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CONTENTS

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MATHEMATICS IN NINETEENTH CENTURY SCIENCE[1]

THE treasures of one age are the rubbish of the next age. Ideas, like things material, are mostly transient. The present possesses but little of that which the past, with infinite labor, has acquired. Our estimate of values changes from century to century, and often with reason: what was once useful is found under later conditions to be wasteful, and new knowledge piles old machinery upon the scrap-heap.

Considered in this light, the science of even one hundred years ago looks antiquated to a schoolboy of to-day. But what of the exceptions? Not all knowledge is novel, and there are indispensable truths and fundamental principles that were discovered thousands of years ago. Most of our exact science is, however, new since the time of Galileo, Bacon and Newton; and it is probably not far from the truth to say that three fourths of the knowledge at present constituting exact science was discovered in the course of the nineteenth century.

Every generation must either advance, or lose much of what it has inherited; only as it is used for finding new knowledge is the value of the old science understood. I speak to-night to a group of younger students of science, into whose hands are committed from the past whatever they can use of accumulated knowledge; and who have announced, by the badge of Sigma Xi, their devotion to the highest ideal in science, that of increasing its definite content

[1] Address before the Syracuse Chapter of the Sigma Xi, March 15, 1915.

and improving its applications for the welfare of all men.

Every man must do what he can—hence comes specialization. Mathematics is and has been a useful kind of work, of value both immediate and prospective. It is of that I am to speak here briefly. On its utility I need touch but lightly, mentioning a few of the most obvious contributions to other branches of science; then I must point out more at length certain particular mathematical theories and bodies of reasoned abstract knowledge developed in the past hundred years.

These latter take their chance of survival along with the poetry, the art, the philosophy of their time—and indeed with much of what is now received as natural science. If it survives, it will be because you, and others like you who are to become intellectual leaders in the near future, find in these fields tasks which seem to you worth the doing; things begun which you would gladly finish, errors which must be cleared away to make room for truth; ideas in germ or questions vaguely hinted at, which can be worthily developed by your arduous labor.

First, then, let us recall some of those mathematicians whose labors have enriched other natural sciences since the time of Lagrange and Laplace. Four physical problems of major importance have demanded the devotion of mathematicians of the first rank, and have given occasion for the elaboration of theories now generally accepted. These are the problems of the transmission of light, of electrical and magnetic effects at a distance, of the relation between heat and other forms of energy in the world of force, and the historical question concerning the origin and growth of the earth on whose surface we live.

Not that the statement of a physical theory requires a mathematical mind; indeed the observatory and the laboratory are far more likely to be the birthplace of theories than the computing room or the logician's study. But whoever formulates a physical theory with precise terms, definitions and laws, and tests it for consistency of its parts and agreement with a wide range of facts—he is a mathematician; and if the complexity of his problem drives him to invent new concepts or new short-cuts in argument, he is a creative mathematician.

Such was Fresnel, who in 1817–19 analyzed and pushed to precise formulation the theory of wave-motion in the luminiferous ether. The hypothesis of an ether was not unknown at that time, and in acoustics the undulation theory was well established. Authorities, however, seemed overwhelmingly in favor of the emission theory of light—Descartes, Newton, Brewster, Laplace and Poisson. It required the resolute and unperturbed mind of a true investigator to give due attention to the hypothesis, then far from orthodox, of an all-pervading ether, and to build up a complete theory of the phenomena of diffraction until it brought him to a crucial experiment, which even his opponents admitted to be decisive. When its implications were completely analyzed and their consequences demonstrated, doubt and prejudice gave way to clearness and certainty. The controversy was practically closed when in 1820 Fresnel received the medal of the Paris Academy for his essay on "The Diffraction of Light." And this general indorsement of the ether hypothesis was most essential for the next pressing problem, that of the transmission of electrical effects.

The effect of a small closed current of electricity upon a magnetized particle in its field is like that of a magnet, feeble or strong, standing at right angles with the plane of the current. One closed current attracts or repels another, just as one

magnet acts upon another; and a current closed or broken in one circuit occasions a current in another closed circuit. Experimental studies of these phenomena by Faraday and Weber revealed quantitative laws, but seemed to show instantaneous effects—forces acting at a distance with no delay in time. The marvellous intuition of Faraday, not himself an analyst, but certainly a profound inventor of geometric motions, created an ideal structure of tubes of force, with something flowing through them under hydrodynamical laws. This bold concept served as basis for the calculations of three mathematical minds that took up his great problem. Sir William Thomson, later known as Lord Kelvin, Helmholtz and James Clerk-Maxwell, each in his own way set forth, in precise notations, equations describing the amount and direction of the transmitted forces. Thomson and Helmholtz ventured hypotheses upon the nature of the transmitting medium and its motions, culminating in those vortex-rings and vortex-sheets which were studied eagerly two decades ago.

A closed vortex-filament in a perfect fluid was shown to be indestructible, and ardent was the hope that properties and differences of vortices would be found analogous to those of the indestructible atoms of chemistry. But the third, Maxwell, penetrated in another direction, and showed what ought to be the rate of transmission of electrical impulses or waves, through an ether such as carries waves of light. The result, that electrical effects travel with the speed of light waves, shows logic outrunning even imagination. Hertz, almost the equal of these three as a mathematician, still greater as an experimenter, actually sent out and collected again such waves, a hundred thousand times longer than waves of light, reflecting and refracting them like light, and so confirmed the speculative conclusions of Clerk-Maxwell. In this exciting race to show the analogy, resemblance, or even identity of things apparently unlike, the study of vortex-rings was suffered to lapse. Or was it because physicists perceived that atoms were not so simple as had been supposed; that it would require, for the explanation of a single atom, more than one ring, however intricately self-involved? At any rate, there remains that one fragment of theory to be revalued and completed by some genius of a future generation.

Certain passages in the preface of Maxwell's "Electricity and Magnetism" show so clearly the relation of mathematical to experimental science that I can not refrain from extracting them verbatim; but first I will quote a general remark from Samuel Beidler upon accuracy.

> The appreciation of the value of accuracy is a thing of modern date only—a thing which we owe mainly to the chemical and mechanical sciences, wherein the inestimable difference between precision and inaccuracy became most speedily apparent.

Maxwell's idea of the way in which deductive methods come to be applied to phenomena is compressed into these two passages. Observe that measurement is fundamental.

> I propose to describe the most important of these phenomena [electromagnetic], to show how they may be subjected to measurement and to trace the mathematical connections of the quantities measured. Having thus obtained the data for a mathematical theory of electromagnetism, and having shown how this theory may be applied to the calculation of phenomena, I shall endeavor to place in as clear a light as I can the relations between the mathematical form of this theory and that of the fundamental science of dynamics, etc.
>
> There are several treatises in which electrical and magnetic phenomena are described in a popular way. These, however, are not what is wanted by those who have been brought face to face with quantities to be measured, and whose minds do not rest satisfied with lecture-room experiments.

Though he insists that Faraday's methods were mathematical, merely expressed in symbols different from those usual among other mathematicians, yet the world knows that Faraday's labors could not have borne such abundant fruit, had there been no Maxwell to interpret and push to their limit his theories. By the combined labors of physicist and mathematician it was finally established that electro-magnetic action at a distance is due to disturbances of the same ether which conveys light-waves, and that this action occupies measurable time; that its velocity is indeed that of light itself, and that light-waves are of the same nature as those sent out from an electric current periodically interrupted. Compare this certainty with the state of doubt, at the beginning of the nineteenth century, upon the relative merits of the corpuscular theory and the undulation theory of light. Refined measurement and rigorous logic had indeed produced a visible effect!

In 1873 was published Maxwell's immortal treatise on "Electricity and Magnetism." In the same year appeared the first work of Josiah Willard Gibbs, then a young professor of mathematical physics in Yale College, on "Graphical Methods in the Thermodynamics of Fluids"; and only five years later his most important work, "On the Equilibrium of Heterogeneous Substances." By this time the great law of the conservation of energy was fully recognized, but its detailed implications were mostly still vague and imperfect. It was certain, however, that in each conversion of energy into other forms there was a degradation of a part: that not all the energy present could ever be utilized as mechanical force; some small percentage was always reserved in the form of heat, or electric potential, or chemical energy, or otherwise. Some vaguely understood quantity called entropy was in the field, so that the total of energy present was divided between entropy and free or available energy. Gibbs set himself the problem: Given all the masses and energies present, of every particular kind, in a physical event, to specify the amount of each kind that will be present when equilibrium is restored. In short, he wished to express as precisely measured quantities the facts implied in the conservation theory. As a corollary, he verifies the brilliant dictum of Clausius, that entropy is a continually increasing quantity.

There is evidence that Maxwell's work waited fifteen years for its full effect to be felt in the scientific world. Gibbs's researches and theories waited somewhat longer, but are now recognized quite generally (I quote his biographer) as being "among the greatest and most enduring monuments of the wonderful scientific activity of the nineteenth century." One may say in brief that Gibbs passed from known laws of physical and chemical action in infinitesimal regions, to reach the succession of transient conditions and to describe the limiting condition of equilibrium, toward which the total finite mass must tend—a maximum of entropy, a minimum of free energy. It is certainly plausible to say that as he dealt with infinite systems, varying from point to point as well as in time, he was forced to invent statistical methods and to rely upon the theory of probability. The most remarkable feature of his work was the fact, noted by his French and German translators and editors, that its theorems reached beyond truth as experimentally known, and served as guides for laboratory research. To paraphrase his biographer, the important and admirable thing in his work is not any new physical hypothesis, but the extraordinary mathematical power which deals simply and rigorously with relations of great apparent

complexity. It is not surprising therefore to find Gibbs almost equally distinguished in difficult fields of pure mathematics, the geometry of N dimensions and in vector algebra.

I have not yet mentioned astronomy, nor living scientists; but can not forbear to call your attention to the apparent decline and fall of the Laplacean theory of the earth's genesis from a nebula, its slow concentration and shrinkage. Two eminent scientists of the present day, Chamberlain and Moulton, have resolutely insisted upon precise formulation of hypotheses, have subjected them to calculation as exact as the case admits, and seem to have established the superior probability of their planetesimal hypothesis: that the major part at least of the earth's mass is the result of slow accretions from intercepted streams of meteorites. It may be that a new theory of nebular evolution must be constructed, starting from the spiral arrangement visible in so many of Hale's and Ritchie's photographs. Certainly there is a strong temptation for younger scientists to join in the working out of this great problem, now successfully past its initial stage.

Most scientists can and will become mathematicians when their special problems reach the stage where measurements are possible, and pure mathematicians should be eager to discuss concrete problems when they see the possibility of applying methods that they understand. But there is an independent territory of pure mathematics, a realm of the understanding and the reason. Its fields have been explored, subdued and cultivated by men of genius, men of strong imagination, men of patient diligence, and by adventurers, ever since the beginnings of history. If the triumphs of natural science loom larger before the eyes of the average man, it is on account of his intellectual position and the distortions of perspective. Has man yet included in his scientific knowledge such a part of the now knowable universe as would be represented by any finite fraction, however small? Is all that the whole race has known, compared with the secrets yet to be discovered, as considerable as the smallest twinkling star among the fiery millions of the galaxy? Are not all scientists, with Sir Isaac Newton, children wandering beside the sea and gathering the pebbles that please them? The intellectual booty gathered by pure mathematicians in the past century was relatively not less magnificent than the fragments of understanding secured by scientists of the concrete; nor is the one kind, in the last analysis, more purely intellectual than the other. All true science is rational, and belongs equally to the reason. I shall name but few of the nineteenth century discoveries in pure mathematics, and not, perhaps, the most important; for in the record of times so recent each will necessarily praise the things that he himself has most admired.

Geometry has made more numerous and more important advances than in the previous three centuries. Her devotees have been numbered by the hundreds. Read the appreciative chronicles of Professor Gino Loria in "Il passato ed il presente delle principali teorie geometriche," in which he sets forth a noteworthy thesis, first propounded by the great French geometrician, Chasles. This science, he declares, is the most attractive, because the humblest worker may hope by diligence not merely to survey the edifice, but to build it further. Genius is no longer indispensable to him who would add a stone to its walls. This exhortation is equally valid to-day; and for this reason a young mathematician may well devote some time to geometry, even if his ultimate dream leads elsewhere.

The earliest years of the century saw the

rise of a geometry freed from Euclid's postulate of parallels. The chains forged by habit and by authority were broken, and with ease when once they had dared the attempt, men found that the existence of one parallel to a line through a given point was not the only workable hypothesis: all other axioms and postulates of Euclid might stand, while instead of this one they substituted either *no parallel,* or *more than one.* Lobachewski, Bolyai, Saccheri, and probably the great Gauss, were leaders in this memorable emancipation. It was left for the later decades to reflect upon the reasons and to furnish illustrations of the various possible kinds of systems of points, lines and surfaces. Along with parallels, of course right angles, the measures of all angles and the measurement of distances were subjected to revision; and late in the century Cayley and Klein invented the theory of projective measurement of linear segments and of angles, to re-combine the divergent kinds of systems into one harmonious theory. It is easy to misunderstand. I do not mean to say that non-Euclidean geometries require substantiation or sanction from the older system of Euclid; or that the kind of space which they describe presupposes a Euclidean space within which it may exist. The question of the true nature of the space we live in is equally foreign to all pure geometries. But our common experience accords sufficiently with the description given by Euclid, and men will always, no doubt, find his axioms preferable. Hence it was and always will be advantageous for us to have as illustrations of non-Euclidean geometries pictures of definite portions of Euclidean space and of objects therein which fit the described relations of other systems in other kinds of space.

Fortunately for my present theme, and its secular limitation, the end of the century brought a full and satisfactory discussion of the fundamental postulates of geometry, by Hilbert of Göttingen. This gave us a model for the examination of not only the traditional Euclidean and the two traditional divergent non-Euclidean geometries, but also for the testing of any other proposed system of fundamental postulates. For the first time, the consistency and independence of sets of axioms were tried and proven. And this was a boon equally to teachers of all grades; for the redundancy of text-book definitions and axioms in geometry had become an intolerable incubus to teachers of critical classes, who yet had not the patience nor the time for finding the solution of their own difficulties. Kant lived and philosophized too early. Axioms must now be judged by their utility for the purpose intended. But whatever they have lost in sacrosanctity and authority, far more is gained in freedom and in power.

Chronologically it is false, but in the inevitable logic of events it is true, that projective geometry developed simultaneously with non-Euclidean. The latter clung to measures but looked at parallels differently, the former viewed distance as changeable and considered parallels as intersecting. Descriptive geometry, the body of rules and relations collected in orthogonal projection, parallel projection, and central projection, acted as a stimulus or challenge. Here were a set of observed phenomena, partly reasoned, ready for precise definition and logical arrangement. On the other hand were visible the beginnings of algebraic geometry, presenting general methods and highly general theorems, threatening to engulf and obliterate all pure geometry except the most elementary. Let any student of analytic geometry reflect on how few theorems from elementary geometry the whole analytic superstructure rests! No wonder that those who preferred things rather than

symbols seized the most obvious means for enlarging the scope and abbreviating the processes of their favorite science! Into the existing knowledge they brought order and system, circumstances of the time gave it rapid development, and a new branch of science came into being.

So projective geometry was cultivated. It was the avowed rival of algebraic geometry. The problems solved and new theories advanced by Monge, Poncelet and Steiner were matched by the genius of Plücker, Moebius, Cayley, Clifford, Cremona and Sylvester. The theorems of the one kind, resting on algebra, were perfectly general; those of the other, founded on intuition of real elements, were compelled to state exceptions. To escape this obstacle, Poncelet stated the postulate of continuity, a logical, almost magical bridge over the lacunæ. But in algebra, when real quantities failed, there were the imaginary quantities to fill the gap. What could pure geometry exhibit as justification or explanation of the continuity that she had postulated? It was a recluse professor in a provincial university, von Staudt, of Erlangen, who settled the matter once for all with a perfect analogy. As algebra defines imaginaries by real quadratic equations whose roots are not real, so, according to von Staudt, geometry defines two imaginary elements by two real pairs of elements. In certain relative positions these determine two real elements; otherwise they stand as a real representation of two imaginaries. This is genius: to define the required object by the very phenomenon which constitutes the demand. What is sauce for algebra is sauce for geometry, and the imaginary elements are since that time the secure possession of both.

What then were the conquests of algebraic geometry? The ancients had examined conics and conicoids, that is, circles, ellipses, spheres, ellipsoids, and those alluring surfaces, the paraboloids, all loci of the second order. Sir Isaac Newton had made a pioneer study of plane curves of the third order, a venture in which for more than a century only two had followed him, until Moebius and Pluecker, about 1835, resumed the attack. It would take many hours to name in most concise form the new features and new problems that arose from this study. Inflexional points, Steinerian correspondences, poloconics, harmonic polars, Cayleyan and Hessian covariant curves—these will serve to remind some of you of the multiple ramifications of inquiries that began on plane cubic curves. Others will recall the metrical properties of semicubical parabolas and cissoids. Of quartic curves, the next higher order, even more is to be said—or omitted; their 28 double tangents and 24 inflexional points and many seemingly elementary problems connected with them remain unfinished, as students in all lands can testify, among others not a few Americans who have given labor and time to them.

Progress is often along converging lines. While geometry advanced steadily in the algebraic direction, algebra was acquiring a new concept, that of a GROUP of operations. Any set of operations form a group, when two of them unite to form always a third in the same set; thus, uniform expansions and contractions of an object form a group, and in numbers all multiplications and divisions together form a group. Now a group of operations will change some things and leave others unchanged or invariant. In algebra, the group of linear substitutions was the first to attract attention, and between 1845 and 1865 the study of this group was the most conspicuous business of algebraists. Soon it was recognized that in geometry all projective transformations constitute a group, and that

this is precisely the same as the group of linear substitutions, if points in space are given in rectilinear coordinates. From this it was not a long stretch to the conjecture that the properties of objects unchanged by projection must be expressible in some way in terms of the invariants discovered by algebraists. To work out this thought demanded the ardor and mathematical ingenuity of a race of intellectual giants like Cayley and Sylvester, Aronhold in Berlin, Hermite, Clebsch and Brioschi. Through their toil a special calculus was developed, and some progress made toward answering the central question: What, under the projective group, are the different possible invariant properties of single algebraic loci, and what the chief invariant relations of two or more loci or systems of loci? Here then was established a definite standard, by which it could be judged whether geometry was a science, or only the ideal program of a science. The group of operations, the simplest objects to be considered, and the invariant relations of those objects under the group: these covered the content, at least of projective geometry.

Probably no climax of equal significance for pure mathematics has been reached since Newton and Leibnitz took the scattered fragments of a theory of limits and from them created the differential and integral calculus. It was in 1872 that Felix Klein published from the University of Erlangen a brief program, or formal address upon assuming a professorate. The title was: Comparative observations upon modern geometrical investigations, and its central thesis was in essence the formal definition, just now mentioned, of geometry. There are many sorts of geometry, but all are alike in this, that each studies its own peculiar group of transformations, and seeks to discover and classify the properties of objects which are invariant under all the transformations of its group. This was then verified by a survey of all kinds of geometry developed up to that epoch.

Of especial interest is of course our elementary geometry, the standard Euclidean. We know its objects; what is the GROUP that it studies? Klein answers: The absolute position in space may be changed, for that change no one can distinguish. An exchange of right for left, as in the space seen in a mirror, does not alter relations that we call geometric. Moreover all size is merely relative, hence uniform expansion or shrinkage in all directions is an operation of the group. Hence rigid motion including rotations, homogeneous expansions and reflections against a plane, those with their myriaform resultants constitute the group of ordinary geometry. I have mentioned the group of projective geometry; others are the geometry of circles and spheres, admitting to its group all operations of elementary geometry and in addition all reflections upon spherical mirrors; the two kinds of non-Euclidean geometry, the four-dimensional geometry of lines, inaugurated by Plücker, and the geometry of contact-transformations, defined and begun by Sophus Lie, of Norway. Many others can easily be noted and named, all fitting Klein's description in so far as they are developed, by any student of mechanics, hydrodynamics, optics or indeed any perfected theory in physics. As science tends to become deductive, and as geometry is the most complete type of a deductive science, and now since Klein's program elucidates the ideal or norm of geometry, so it may well arrest the attention and illuminate the procedure of every systematic scientific investigator.

It must have been this mode of conceiving the essence of geometry that was before his mind when Gino Loria, the historian of modern geometry, wrote the fol-

lowing passage in the epilogue of his famous book:

The figures of geometry which once appeared rigid and motionless—as one might say, lifeless, acquired from the theory of transformations an unlooked for vitality, by virtue of which they were changed one into another, disclosing thus kinships before unknown and establishing relations which had been previously not even suspected.

This expresses well the esthetic feeling of a scientist who ponders upon the meaning of his work, and it contains a hint of the mystery of the fleeting fact and the truth which endures.

Within the century we see geometry coming to definite ideal statements of her foundations and her aspirations. Hilbert has described the one, Klein the other. No longer are we to see interminable debates concerning empirical warrant or intuitive warrant for the truths of this exalted science; though these debates may be profitable, they are not geometry. Mathematics begins when we are agreed upon premises. No longer is there to be the illusion of completeness, as if the problems could all be finished, their invariants determined and interpreted. The question for an investigator who considers a problem is now that of the miner who is prospecting for precious metals; he must ask himself: Have questions like this proved simple enough to be solved, and have the results proved interesting or useful? As for the range of choice, there are appallingly long lists of classes of geometries in the new "Encyklopädie der Mathematischen Wissenschaften." Some I have named: differential geometry is full of attractions; the study of twisted curves and of the systems of curves on surfaces is practically still in its beginnings, with vigorous workers calling for recruits; finite point-systems have claim to early consideration; manifolds in space of more than three dimensions will later assume increasing importance; recent procedures in analysis must some time be subjected to geometrical statement in the hope of simplification; and nothing could be imagined more exciting than the geometrical and kinematical speculations upon the configurations or constellations that the physicists call atoms and molecules.

My choice of topics has been apparently capricious, for there is matter of importance and intense interest in all directions. It is worth mentioning that no fewer than five living Americans have produced books on the theory of functions, or some great division of that subject. Elliptic functions and the vast subject of hyperelliptic and Abelian functions are temporarily less active, while differential equations, and their successors, integral equations, are in the forefront of progress. The theory of numbers in its modern form dates back only to 1800, and teems with marvels unforeseen. It is within fifty years that Lindemann succeeded in proving the number π transcendental—the ratio of circumference to diameter, and it was almost twenty years later that the base of Napierian logarithms, the number e, was put into the same category. The classification and discovery of transcendental numbers is still going on. Concerning the combinatory analysis with its store of theories yet incomplete, one does not need to bring news to Syracuse, nor coals to Newcastle. But I may mention the researches on point-sets, set in motion by Kantor at Halle, and refer you to the summary views and keen commentaries of Van Vleck, professor in the University of Wisconsin, in his recent address as retiring president of the American Mathematical Society.[2]

The close of the past century saw the extraordinary growth of scientific societies, and in particular of mathematical societies. Three I may instance, all less than thirty

[2] See SCIENCE, Vol. 39 (new series), pp. 113–124.

years old with active membership ranging from 600 to over 900, the American, the German, and the Italian in Palermo. Taken with other things, these are signs of a flourishing condition of scientific thought. Possibly the most striking proof of this, so far as mathematics is concerned, is found in the annual quantity of published research which more than doubled during the last thirty years of the century.

No one understands the group of transformations which we call the flight of time, yet it acts unceasingly upon all human possessions. Nor are its invariants known; nor yet can we determine what part of scientific energy is conserved and what part is entropy, or waste. It seems to us now that the few great lines of development that I have so briefly traced do show permanent tendencies of organized knowledge—that in these directions science will at least not retrograde while our civilization endures. Yet it is already evident that the last word has not been spoken in physics, and conceivably the time may come when the names of Helmholtz, Kirchoff, Maxwell and Hertz will be venerated as that of Archimedes now is—hardy pioneers indeed, but no longer in the vanguard. Let me make the trite remark, that the transformations of time work more slowly on the body of treasure that we call pure mathematics than they do upon the far greater and more rapidly growing pile of natural science. The reason is obvious; natural science deals with an infinite number of data, and can never apprehend them all; hence she makes hypotheses serve temporarily. Mathematics does the same, but perfects her products by the progressive exclusion of conflicting data; that is to say, by increasing precision of terms. The Pythagorean theorem concerning the sides of a right triangle will be true longer, in the very nature of things, than Sir George Darwin's magnificent theory of the tides. This which is from one point of view a reproach to pure mathematics, constitutes on the other hand one of its titles to immortality.

That the literature of our science is vast and complicated shows only how many are the things that men have wished to know. More numerous, with every advancing decade, are the questions pressing for solution. It will not be your lot, members of the Sigma Xi, to discover anything so simple, necessary and universally useful as the multiplication table, or the common theorems upon volumes and areas; but you may find something as useful to mankind as Napier's logarithms, which were new only three centuries ago; or some theory as beautiful and perfect as that of elliptic functions applied to plane cubic curves. You may contribute to the labor of other scholars something as helpful as the great "Encyclopaedie" of the mathematical sciences, now almost completed by the untiring labor and devotion of cooperating mathematicians in all lands, but chiefly by Germans. But in whatever large domain or narrow field you may elect to labor, I give you the cheering assurance that there are fruitful discoveries that can be made by every toiler; that to each one who has the *will to know,* will come those rare and golden moments when he shall shout in triumph, with the ancient truth-seeker Archimedes, *Eureka!*

Henry S. White

Vassar College

SEEING YOURSELF SING[1]

It is possible to make vibrations which produce a tone to the ear also produce a picture to the eye—a picture which reveals details of pitch faithfully and far more finely than the ear can hear, and which may, therefore, be

[1] A part of a paper read before the meeting of the National Music Teachers Association in Buffalo, New York, December, 1915.

employed for the objective measurement of pitch and as a guide in training to sing and play in pitch. The singer standing before an instrument sees in clear pictures every pitch movement of the voice as he is singing; he sees exactly how many vibrations per second the vocal organs are producing, and thereby can tell, at the very moment of singing a note, what error is involved, even down to the hundredth of a tone; he can practise before the instrument by the hour with the opportunity of seeing the error in every tone and controlling the voice and the ear by the eye at pleasure; he can study in detail the attack, the sustaining, and the release of a single note; the player of the violin, flute, cornet, or other instrument may treat his instrument in the same way; a person at a distance may connect "long distance" with the tonoscope and project his voice or instrument on this screen hundreds of miles away; a scientist or a musician may take a phonograph record of the tonal effects under observation and ship the cylinder to the laboratory, in which it may be reproduced upon the tonoscope; the student of primitive music can transcribe the phonograph record by this method; the scientist can undertake technical studies on pitch which involve exact measurements and instantaneous recording in actual singing; the student of public speaking can study the inflections of the voice objectively and train for mastery; the teacher of the deaf can place his pupil before the instrument and train him to speak with pleasing inflection of the voice by practising with the aid of the eye.

This array of claims may seem extravagant, but these and many other related achievements are made possible by the development of a ready and accurate method of registering pitch. The instrument which will do this is known as the *tonoscope*, and is now available for use in the studio, having been placed on the market in December, 1915.

THE TONOSCOPE

The tonoscope[2] shown in the accompanying illustration[3] works on the principle of moving pictures, technically known as stroboscopic vision. It converts the sound vibrations into pictures on the screen. The screen, which may be seen through the opening on the front, has eighteen thousand and ninety-five dots so placed

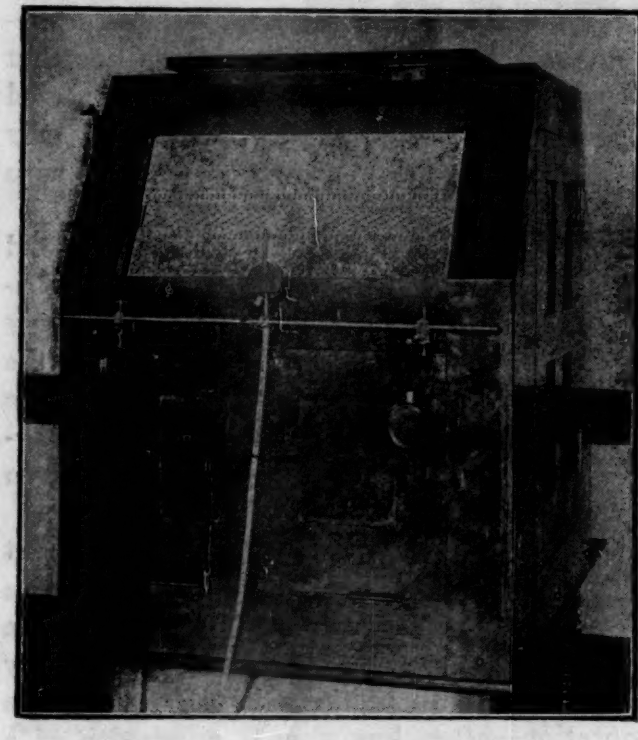

FIG. 1. The Tonoscope.

that, when acted upon by a sensitive light, they arrange themselves in characteristic figure for every possible pitch within the range of the human voice. Each figure points to a number on the screen which indicates the pitch. The dots are arranged into one hundred and ten rows; the first one has one hundred and ten dots, the next one, one hundred and eleven dots, and so on, each successive row having one more dot than the preceding one, up to the last, which has two hundred and nineteen. When the tone is sounded, the row which has the dot frequency that corresponds to the vibration frequency of the tone will stand still, while all

[2] A full account of this instrument by the present writer, and an article by Dr. Walter R. Miles reporting investigations made by means of it, are to be found in the Psychological Monograph No. 69, pp. 1–66, *Psychological Review*, Princeton, N. J.

[3] In this illustration the sensitive flame is energized through a microphone; but ordinarily, simple air transmission to the manometric flame through a speaking tube is used.

other dots move and tend to blur. The row which stands still, therefore, points to a number on the scale which designates the pitch of the tone. The screen contains a sufficient number of rows of dots to cover exactly one octave. Tones above or below this octave are read on this same screen by multiples.

To see the pitch of the tone, one has, therefore, only to see the number of the line that stands still. The tone may be sung or played under natural conditions. Indeed, one may register the tone from any distant point with which there are telephone connections.

The instrument is operated electrically and will run indefinitely without any care or disturbance. This makes the tonoscope a ready and continuously available instrument in the studio or the laboratory. The speed of the revolving screen is controlled by a tuning-fork with which it must keep step, being driven by a synchronous motor.

In other words, we have here an instrument which will transform the vibrations of voice or instrument to visual configurations on a scale that indicates the actual pitch of any note down to an accuracy of a fraction of a vibration—often less than a hundredth of a tone. Indeed, if we are dealing with a note as constant as that of a tuning-fork or a string, the pitch will be recorded accurately in tenths of a vibration, because fractions of vibrations may be read in terms of the number of dots that pass per second in the slowly moving line.

There are various graphic methods of recording pitch in use, but these are entirely too laborious and cumbersome for practical use. The tonoscope furnishes us the first ready and at the same time reliable and accurate means of registering directly the pitch of a tone as sung, spoken, or played with a musical instrument in such form that it can be operated with convenience and safety outside the technical laboratory.

THE SIGNIFICANCE OF THIS INSTRUMENT FOR THE SCIENCE OF TONES

The psychology of music on the sensory side has been studied with fruitful success in recent years. But the motor side of the process—the psychology of tone-production and tone-control—is practically unworked and remains largely in the realm of mystery chiefly for the want of a measuring instrument. The introduction of a ready means of recording, analyzing and projecting sound vibrations before the eye therefore opens up a most wonderful field of research both in pure science and in the art of music.

Up to the present time there has been only one tonoscope available, that in the psychological laboratory of the University of Iowa. This has passed through several stages of improvement during the last fifteen years; and this single instrument in its various stages of development, in the hands of a small group of investigators, has been a valuable aid in the discovery of interesting facts in the psychology of music. The scope of the work which has thus been opened up by investigations already undertaken may be illustrated by the naming of the principal problems which have been investigated up to date, to wit: the comparison of men and women as to ability in singing of true pitch, under a large number of controlled conditions; relative accuracy of pitch within the tonal range, under various conditions; principles involved in the singing of large and small, natural intervals and more artificial intervals; the effect of the strength of the keynote upon the accuracy of reproduction; the effect of the volume of the voice upon the pitch; the variation of pitch with vowel quality or timber; the correlation of ability to sing in pitch with pitch discrimination, tonal memory, tonal imagery, sense of consonance, musical education, and other factors; the establishment of norms for the measurement of ability to sing in pitch; and the study of the effect of training the ear by the aid of the eye. Some of these are reported by Miles in the article referred to above, Psychological Monograph No. 69. The scope of this paper will permit the discussion of only one of these, and for this purpose, the last mentioned may be chosen.

TRAINING THE EAR BY THE AID OF THE EYE

The practical use of the tonoscope in the

studio lies in the training of the ear and therefore, indirectly, the control of the voice or instrument by the aid of the eye. On this point we have conducted a number of series of experiments to determine the effectiveness of such training as evidenced, *e. g.*, by the kind, the rate, the degree, and the permanence of the improvement gained by practising with the instrument. The first of these series was begun in 1903; from that time up to the present, experiments in the training of pitch control have been in progress continuously for purposes of developing methods and means and testing results. Laying aside all technical matters and detail, we may glean from these experiments the following points of interest:

Practically all singers—good, bad, or indifferent; trained or untrained; child or adult; professional and non-professional—will improve in pitch control by training with the instrument. He who can not sing a tone may "find" himself by the eye; the average singer is slovenly about pitch until shocked by what he sees in the projected voice; the person who can sing to a high degree of accuracy—say an error of plus or minus one vibration—has abundant room for improvement within a fraction of a vibration, for the more accurately one sings, the finer the instrument registers.

The gain in training by aid of the eye may be attributed in large part to the recognition of certain subjective and objective sources of error which may be eliminated after discovery by the instrument. The ear unchecked is lax in its control of pitch. When the eye reveals an error in pitch, it aids the ear in identifying and making concrete the elements of hearing which had before remained undifferentiated and unrecognized. The seen tone serves both as a whip and as a guide in pitch near the lower limits of the ear, and is, therefore, the best incentive for improvement. Among the objective disturbances are the effect on pitch of the loudness of the keynote heard, the loudness of the note sung, the quality of the tone heard, the quality and register of the tone sung, the vowel of the syllable sung, the duration of the tone, etc. Among the subjective factors the most complicated one is the factor of effort of attention. Ordinarily one sings more accurately when he tries; yet when one comes to a certain stage he will sing better if not conscious of a specific effort to sing in pitch. Fears, theories, anticipations and illusions also modify the pitch. Under certain circumstances accuracy in pitch may be a mark of the general condition of the system.

Training with the eye improves the ability to form concepts of intervals and sing them with increasing accuracy. Who can sing, or knows when he has sung, the chromatic scale or even a single half tone? With the instrument he can place the exact note in tempered scale or in just intonation and study in detail effect after effect and control for mastery with the instrument which registers much finer distinctions than the ear can hear. Here again we have found that there is room for improvement for all. One man who thought he was tone-deaf was trained to sing a tone interval with a high degree of accuracy. One well-known singer was struck with despair when she saw how badly she sang the natural scale.

Training the ear with the eye enhances its ability in voluntary control of the voice as in raising and lowering of the pitch. The improvement in this is astonishingly rapid; and the reason for all this rapid improvement lies in the fact that one sees the tone the moment he sings and hears himself sing it, and can at will identify the direction and exact amount of the error. As has been pointed out, this seeing of the tone serves as a whip and also as a guide to specific effort.

Striking a note may be fractionated, *i. e.*, separated into its parts so that one may study from moment to moment, the attack, the release, and the sustaining (with its various periodic or progressive changes in pitch, both desired and undesired). The instrument enables the singer to take each of these in turn and establish mastery under the criticism and guidance of the eye.

The gain made in singing with the aid of the eye is transferred into auditory and motor control. The improvement which takes place in singing with the instrument is very rapid and one would, therefore, suspect that

it would not be permanent. But experiments show that if the training is continued for a few days with the instrument, the gain will be transferred to the ordinary singing without the instrument. This is the most encouraging feature in the process and deserves to be analyzed in great detail for the purpose of a pedagogy of singing; this we are now attempting to do in the laboratory. Such questions as these arise: How is association transferred from the visual to the auditory-motor? What are the common elements in visual and auditory control? How can we isolate each of these factors for the purpose of reduction of error?

This type of training is convenient, inexpensive and rigid. The pupil may be assigned any one of a hundred exercises in pitch training and practise all by himself under correction at every tone production; it may be to reduce a tendency to sharp or flat, to eradicate a tremulo, to gain control of a vibrato, or any other pitch figure the master may set. It gives opportunity for control drill under the severest correction at every stage.

CARL E. SEASHORE
UNIVERSITY OF IOWA

ORVILLE A. DERBY

IN November last the newspapers published a cablegram from Rio de Janeiro announcing the suicide of Orville A. Derby, director of the Brazilian Geological Survey. Letters from mutual friends have now thrown all the light on the subject that we can reasonably expect to get.

Mr. Derby first went to Brazil in 1870 as student assistant of Charles Fred Hartt, who was then professor of geology at Cornell University. He made two other vacation trips to that country, and went to Brazil finally in 1875 to be assistant geologist to the newly established geological survey of the Empire, and lived there the rest of his life. In 1877 the survey was suspended, and Professor Hartt, its director, died at Rio. Mr. Derby was shortly thereafter appointed curator of geology in the National Museum at Rio, and held that position until 1886 when he was put in charge of a newly established geological survey of the state of S. Paulo, a position he held until 1904. In 1907 a new federal survey was provided for under Dr. Miguel Calmon, minister of public works, with Derby as its chief.

The war in Europe disturbed the financial equilibrium of South American countries as well as that of other parts of the world. Brazil was probably obliged to economize wherever it was possible to do so, and this led to the reduction of appropriations for the work of the geological survey to such a point as to destroy the efficiency, and even to threaten the existence of that organization. Probably the necessity for such economies was not apparent to Mr. Derby, and he looked upon them as an attempt to discredit him and the bureau under his direction. In any case he took the matter very much to heart, and his friends find no other reason, or shadow of a reason, for his suicide.

Mr. Derby never married, and he led the solitary life of a recluse and student. He was held in the highest esteem by all who knew him. His whole life was given to the study of the geology of Brazil, and no one, living or dead, knew it as he did, or was more profoundly or more unselfishly interested in it. At the time of his death he had published more than a hundred and twenty-five papers on the geology of Brazil, many of them in the Portuguese language, which he wrote with ease.

His successor as the director of the geological survey of Brazil is Dr. L. F. Gonzaga de Campos, one of the ablest and most trustworthy of the Brazilian geologists, and for many years one of Mr. Derby's most competent assistants.

A fuller account of his life and work will be published in the *Bulletin* of the Geological Society of America.

JOHN C. BRANNER
STANFORD UNIVERSITY, CAL.

PARIS-WASHINGTON LONGITUDE[1]

DIRECTOR B. BAILLAUD, of the Paris Observatory, presented the results of the determina-

1 Translation from *Comptes Rendus de l'Academie des Sciences*, February 14, 1916.

tion of the difference of longitude between the observatories of Paris and Washington, as deduced under the direction of M. Renau, who makes the following statement:

It is now three fourths of a century since the first attempts were made to connect Europe and America in longitude. Gilliss in 1838, by meridian observations of the moon, and later Walker, Peirce, and others, by means of eclipses and occultations, obtained results which were not accordant and showed a range of 2.5 seconds.

About 1849 new determinations were made with the aid of chronometers, but these gave results of little greater precision. Since 1866, several determinations were made by the exchange of telegraphic signals. Gould in 1866, Dean in 1870 and Hilgard in 1872 determined the difference between Cambridge and Greenwich. Hilgard in 1872 determined the difference between Cambridge and Paris, and in 1892 a determination was made between Montreal and Greenwich.

In 1912 Captain Jayne, superintendent of the Naval Observatory, with the approval of the Acting Secretary of the Navy, proposed that a determination be made of the difference of longitude between the observatories of Paris and Washington.

Early in 1913 the Bureau of Longitudes began to study the conditions under which this important work could be undertaken. For some years Messrs. Claude, Driencourt and Ferrié, had been developing the idea of applying radio signals to the determination of the differences of longitude, and due to their remarkable initiative the observatory had been able to successfully measure the differences between Paris-Bizerta, and Paris-Uccle, in 1911 and 1912.

These previous operations seemed to fix the most suitable methods, and to assure the success of the undertaking, though it was necessary to take account of the difficulty of hearing radio signals at a distance of 6,175 kilometers.

Operations began in October, 1913, and continued until early in March, 1914, with an interchange of observers near the middle. The astronomical observations were most satisfactory. It was not until after the middle of November that satisfactory exchanges of radio signals were effected.

Owing to the perfect installations of the clocks at Paris and Washington, which enabled their rates for many days to be determined with a precision at least equal to that of the observations, it was found possible to utilize the evenings on which radio signals were exchanged, when astronomical observations were made at one station only (incomplete), as well as those when such observations were made at both stations (complete).

In the first part of the operations, 7 complete and 14 incomplete evenings were secured and in the second part 10 complete and 20 incomplete evenings were secured. The results are as follows:

Complete Evenings

	h	m	s
First part	5	17	36.53
Second part	5	17	36.75
Weighted mean	5	17	36.65

For all Evenings

	h	m	s
First part	5	17	36.53
Second part	5	17	36.75
Weighted mean	5	17	36.67

The value $5^h\ 17^m\ 35^s.67$ is adopted as the definitive result of our work.

The difference $0^s.22$ between the results of the first and second parts should not be regarded as excessive in view of the peculiar conditions of the enterprise and of the difficulty of the exchange of radio signals. It does not seem capable of explanation without further labor.

In a preliminary publication of the results of the work of the American astronomers, the definitive result is given as $5^h\ 17^m\ 36^s.62$[2] which is within $0^s.01$ of our result, and there is a precisely similar difference between the two parts, $36^s.56$ and $36^s.76$, corresponding to $36^s.53$ and $36^s.75$ as given above.

[2] *Astronomical Journal*, March 15, 1915.

SCIENTIFIC NOTES AND NEWS

Members of the National Academy of Sciences have been elected, as follows: Gregory Paul Baxter, professor of chemistry, Harvard University; Gilbert Ames Bliss, professor of mathematics, University of Chicago; Marston Taylor Bogert, professor of organic chemistry, Columbia University; Otto Folin, professor of biological chemistry, Harvard Medical School; Leland Ossian Howard, chief of the Bureau of Entomology, U. S. Department of Agriculture; Phoebus Aaron Theodore Levene, member in biological chemistry, Rockefeller Institute; Alfred Goldsborough Mayer, director of the department of marine biology, Carnegie Institution; Raymond Pearl, head of the department of biology, Maine Agricultural Experiment Station; Frank Schlesinger, director of the Allegheny Observatory, University of Pittsburgh.

At the recent meeting of the American Philosophical Society, members were elected, as follows: William Wallace Atterbury, railway engineer, Philadelphia; Maxime Bôcher, professor of mathematics, University of Chicago; Percy Williams Bridgeman, professor of physics, Harvard University; James Mason Crafts, professor emeritus of organic chemistry, Massachusetts Institute of Technology; Henry Platt Cushing, professor of geology, Adelbert College, Western Reserve University; Edward Murray East, professor of experimental plant pathology, Bussey Institution, Harvard University; Frank Rattray Lillie, professor of embryology, University of Chicago; William E. Lingelbach, professor of modern history, University of Pennsylvania; Daniel Trembly MacDougal, director of the department of botanical research, Carnegie Institution; Charles Frederick Marvin, director of the U. S. Weather Bureau; Lafayette Benedict Mendel, professor of physiological chemistry, Yale University; Forest Ray Moulton, professor of astronomy, University of Chicago; Eli Kirk Price; Erwin Frink Smith, pathologist in charge, laboratory of plant pathology, U. S. Department of Agriculture; William Morton Wheeler, professor of economic entomology, Bussey Institution, Harvard University. Foreign residents were elected as follows: Frank Dawson Adams, professor of geology, McGill University; Wilhelm L. Johannsen, director of the plant physiological laboratories, University of Copenhagen; Joannes Diderik van der Waals, professor of mathematical physics, University of Amsterdam.

The board of directors of the Hospital for Deformities and Joint Diseases announces that a dinner will be given to Dr. Abraham Jacobi at the Ritz Carleton Hotel on May 3. Dr. Levi Strauss is chairman of the dinner committee.

Professor Antonio Berlese, of Rome, and Dr. L. O. Howard, of Washington, have been elected to honorary fellowship in the Entomological Society of London to fill the vacancies caused by the deaths of J. H. Fabre and Brunner von Wattenwyl.

Dr. Arthur D. Little, of Boston, has been placed in charge of the organization of a Canadian Research Bureau in Montreal which will aim to coordinate the work of scientific men and experts engaged in research work in all parts of the Dominion.

Dr. J. C. Cain has been appointed chief chemist of the British Dyes, Ltd., at present under construction at Dalton, Huddersfield.

Dr. Charles G. Wagner, superintendent of the Binghamton, N. Y., State Hospital for the Insane, was elected president of the American Medico-Psychological Association, at the seventy-second annual meeting held in New Orleans, on April 5.

Dr. James V. May, head of the New York State Hospital Commission, was recently appointed superintendent of the Grafton, Mass., State Colony for the Insane, succeeding Dr. H. Louis Stick, whose resignation was accepted in March.

Mr. Carl Whiting Bishop, of the University of Pennsylvania Museum, has returned to Pekin after three months of exploration in Szechuen province. Mr. Bishop was at Chengtu, the capital of Szechuen province, and traveled some distance northwest from

that point to examine old ruins and make archeological studies.

DR. FRANK A. HERALD has recently returned to America from China, where he has been making geological investigations of the possibilities of oil and gas fields for the Standard Oil Company of New York.

THE staff of the Iowa Lakeside Laboratory of the University of Iowa, on Lake Okoboji, Iowa, will be as follows for 1916: Director, B. Shimek, University of Iowa; zoology, T. C. Stephens, Morningside College; geology, J. L. Tilton, Simpson College; botany, A. F. Ewers, McKinley High School, St. Louis; zoology during August, F. A. Stromsten, University of Iowa. Assistants, D. H. Boot, Zoe Frazier, Eva Cresswell, W. J. Himmel. The regular summer session, during which courses will be offered, will run from June 19 to July 31. The usual research session will be held during August.

THE annual address of the Pathological Society of Philadelphia was delivered by Dr. William H. Park, New York, at the College of Physicians and Surgeons, on April 27.

THE annual Cutter lecture, on "Preventive Medicine and Hygiene," was delivered at the Harvard Medical School on Monday, April 3, by Dr. George W. McCoy, director of the Hygienic Laboratory of the United States Public Health Service. Dr. McCoy, formerly superintendent of the leper colony on the Island of Molokai, Hawaii, selected as his topic, "The Public Health Aspects of Leprosy."

THE tenth Harvey lecture was given at the New York Academy of Medicine, on April 8, by Professor Stanley R. Benedict, of Cornell University, his subject being: "Uric Acid in its relation to Metabolism."

PROVOST EDGAR F. SMITH, of the University of Pennsylvania, was the guest of honor on Founder's Day at Juniata College on April 17, when they dedicated their new science hall. Dr. Smith delivered the principal address, his subject being "A Tribute to the Sciences."

THE seventh of the exchange lectures between the University of Wisconsin medical department and the Marquette University medical school was given by Dr. W. J. Meek at Milwaukee on April 19, on "The Physiology of Adrenelin." The previous lecture was given by Dr. C. R. Bardeen on "The Physical Basis of Heredity."

UNIVERSITY AND EDUCATIONAL NEWS

THE state of New Jersey has recently appropriated the sum of $4,000 to aid in establishing a course in sanitary science to be affiliated with the course in biology at Rutgers College.

NEW YORK UNIVERSITY has concluded an arrangement with the Brooklyn Botanic Garden whereby research courses in botany will be conducted at the garden and credited in the biology department of the university's graduate school. Plant-breeding and plant-pathology will be the principal fields of investigation. The Botanic Garden is a department of the Brooklyn Institute of Arts and Sciences. Its agreement with the university, entered into "for the purpose of encouraging botanical investigation," provides that the instructors in this research work will have the rank of "lecturer" in New York University and the students' work will count for an advanced degree.

The British Medical Journal states that the late Mr. Stanley Boyd left an estate valued at £32,646. After providing for certain legacies he left the residue of his property in trust for his mother and sister and the survivor of them, and subject thereto he gave £2,100 to Epsom College for one foundation scholarship, and the ultimate residue to the University of London for the endowment of a professorship of pathology in the Medical School of Charing Cross Hospital. Out of the property bequeathed to him by his wife he gives a number of legacies to her relatives, £1,000 each to the London School of Medicine for Women, the New Hospital for Women and the Pathological Department of the New Hospital for Women, and any residue to the New Hospital for Women.

THE board of governors of the Western University, London, Ont., has purchased a large

farm near that city for the erection of a new university. The location consists of 100 acres overlooking London. Building operations will not be commenced until the end of the war, but plans will be prepared and the grounds laid out.

Cassius Jackson Keyser, professor of mathematics in Columbia University, and M. W. Haskell, professor of mathematics in the University of California, will exchange chairs for the half-year from August to December, 1916.

Mr. Eliot Blackwelder, professor of historical geology at the University of Wisconsin, has been appointed professor of geology and head of the department, at the University of Illinois. The appointment will take effect on September 1.

There have been promoted to assistant professorships at Yale University, Joshua Irving Tracey, Ph.D., in mathematics and Alexander Louis Prince, M.D., in physiology.

At Rutgers College, Dr. F. E. Chidester, associate professor of zoology, has been advanced to a professorship and made chairman of the course in biology; Dr. A. R. Moore, associate professor of physiology at Bryn Mawr, has been made professor of physiology and head of the newly created department of physiology; and Richard Ashman has been appointed assistant in zoology.

Dr. Wilbur A. Sawyer has been appointed clinical professor of preventive medicine and hygiene in the University of California. He will continue also his work as secretary and executive officer of the California State Board of Health. The object of the creation of this new department is to bring about the most effective possible cooperation between the University of California and the California State Board of Health. The new department will include in its staff Dr. James G. Cumming, director of the Bureau of Communicable Diseases of the State Board of Health, who will become also assistant professor of preventive medicine and hygiene, and, as lecturers in preventive medicine and hygiene, Dr. William C. Hassler, Dr. John N. Force, Dr. Jacob N. Geiger, assistant director of the Bureau of Communicable Diseases, and Chester G. Gillespie, C.E., director of the Board of Sanitary Engineering of the California State Board of Health.

Among promotions at Stanford University are: To the rank of associate professor, John P. Mitchell in chemistry, Leonas L. Burlingame in botany and Rennie W. Doane in entomology; to rank of assistant professor, Hayes W. Young in metallurgy, John F. Cowan in surgery and Perley A. Ross in physics.

DISCUSSION AND CORRESPONDENCE

THOSE FUR SEAL BONES

"Millions of dollars' worth of seal and sea lion bone deposits on the shores of the Pribilof Islands, a vast store of government-owned fertilizer available for practical use," is the way the Washington dispatch of February 28 comments on a report said to have been made by the secretary of commerce to the House committee on merchant marine. One of these deposits is said to be "a mile long by half a mile wide and fully six feet deep." This suggests 83,000,000 cubic feet of bone—a wonderful deposit, indeed! To complete the picture it is stated that raw ground bone was bringing $35 a ton in December.

This sounds like a very important discovery. It will be too bad if it proves not to be true. The dispatch indicates that the deposits "have not been fully surveyed." It is to be feared that the completed surveys will be disappointing.

It is a fact that since the discovery of the Pribilof Islands in 1786 upwards of 5,000,000 fur seals have been killed and their carcasses left to rot on the killing grounds. These are the bones which are referred to. There are no prehistoric bones, since the death of the adult animals from natural termination of life is at sea, under the stress of the winter migration. Of the five million animals killed about one half were deposited on the great killing ground near the village on St. Paul Island.

The rest are distributed over a considerable number of widely separated fields, for the most part unimportant.

The adult male fur seal attains a weight of 400 to 500 pounds, and if this were the class of animal killed, a considerable deposit of bone would have resulted from the carcasses of the five million animals. It is, however, the immature males of two and three years that have been killed. These are animals of 50 to 60 pounds weight and their bones still contain a large proportion of animal matter. The seal is an animal adapted for life in the water, like a fish, and its bones are small and fragile. In a green state they constitute perhaps ten pounds of the weight. Weathered for a few seasons on the sands of St. Paul, or otherwise dried out, they would not exceed three to five pounds in weight. In other words 500 of the animals might give a ton of bone, if it was regularly cared for. Left to chance, the yield would naturally be less. The five million animals would therefore at best represent about 10,000 tons of bone, or at the price of $35 a ton suggested, a total value of $350,000. Half of this would be found in the St. Paul village deposit. This is on the assumption that something like the full product of bone could be recovered.

It would not be all profit; there would be expense in getting the bone out, and especially in shipping it to some commercial port. The Pribilof Islands have no harbors. Ships must anchor a mile or so off shore and all cargo must be lightered in or out in small boats. The islands are small and a few hours' stiff wind will break up a landing any day, twenty-four hours', all landings. On the approach of a storm the ship must pull anchor and put to sea. Fogs are frequent and persistent and a vessel may have to wait days for an observation of the sun to enable it to find its way back to the islands. In the summer of 1914 the supply ship of the department of commerce spent 23 days, at a cost to the government of $250 a day, about these island in landing a cargo of a few score tons of freight. The revenue cutter service in 1911 left the bones of a good ship on one of the reefs of St. Paul. The getting of this supply of bone out (assuming that its exists) would be a thing fraught with difficulty and danger.

But the most probable thing about the whole matter is that the bone deposit does not exist. In the season of 1912 the writer witnessed the sinking of a six foot trench through a considerable portion of the main field of alleged deposit for the purpose of laying a water pipe. No bone was found except at or near the surface and here in negligible quantity. This was a matter of surprise and comment because on theoretical grounds we had expected to find layer on layer of bones representing the successive annual killings which had been going on here for over a century. Nothing, however, was found but the coarse lava sand which underlies the field to a depth of fifteen to twenty feet. Into this sand, evidently, the rain has washed the dust of the bones as they quickly disintegrated.

A more tangible thing associated with this great killing field of St. Paul Island is the oil, rendered by the elements from the blubber encasing the seal carcasses. This has soaked into the ground and mingled with the water that underlies the field giving to it the appearance of thick brown soup. The villagers of St. Paul have had to locate their wells far beyond this field to get pure water. A claim that there were millions of dollars' worth of seal oil stored in reservoirs underneath the Pribilof Island killing fields would have had a more solid basis of fact to rest upon. Perhaps the revelation of this great natural resource is held in reserve.

One interesting thing in connection with these rather mythical bone deposits of the seal islands is that since 1912 no additions have been made to them. The fur seal law of that year stopped commercial sealing. In 1911 the last deposit—the bones of 12,000 seals—was laid down; it represented about thirty tons of dried bone, worth, at $35 a ton, about $1,050. Incidentally the 12,000 seal skins taken from these animals brought the government $35 each, or the reputed price of a ton of raw ground bone. The value of the seal skins, which may in this case be considered a

by-product of the government seal boneyard, was $423,000. The bones of 10,000 to 12,000 seals might have been deposited each year since to increase the store of "government-owned fertilizer," but the fur-seal law has prevented the secretary of commerce from killing them. In addition to the loss of the bone, there has been the loss in seal skins, which in the meantime have risen to a price of $50 each. Incidentally these seal skins, if they could be taken, would also be valuable cargo for the ships "that may be provided by the pending administration ship purchase bill," and less troublesome than bone to handle.

George Archibald Clark

MATERIALS IN A TON OF KELP

The seriousness of the current shortage of potash gives increased importance to a careful consideration of the American sources of it. The following table gives in pounds the quantities of the materials mentioned that are contained in a ton (2,000 pounds) of fresh kelp.

	Water	Potassium Chloride	Other Salts	Iodine	Algin	Crude Fiber	Nitrogen
Nereocystis luetkeana	1,834	52.7	25.1 to 37.7	0.22	23.4	8.4	2.9
Macrocystis pyrifera	1,736	52.5	26.7 to 55.7	0.61	44.4	19.3	4.3
Alaria fistulosa	1,726	39.3	27.6	Trace	No data	No data	7.1

The three species mentioned are the ones that are harvestable in commercial quantities along the Pacific coast of North America. The supply available on the California coast is mainly *Macrocystis*, that in the Puget Sound region is mainly *Nereocystis*, while that in southern Alaska is *Nereocystis, Macrocystis* and *Alaria*. In western Alaska the supply is *Nereocystis* and *Alaria*.

The computations are made from data obtained by workers in the United States Bureau of Soils, the University of California and the University of Washington.

The algin here reported is the adhesive material that can be dissolved in sodium carbonate and precipitated with acids. The crude fiber reported was approximately half cellulose.

George B. Rigg

University of Washington

THE TOXICITY OF BOG WATER

The writer has found by experiments that filtered bog waters show a precipitate when saturated with ammonium sulphate, disodium hydrogen phosphate, or sodium chloride. The filtrate from this when freed from the salt by dialysis did not prove toxic in solution cultures to the root hairs of *Tradescantia*, while the untreated bog water did prove toxic. The matter precipitated by these salts is not volatile at 100° C.

Since the specific gravity of bog water is 1.000, and its osmotic pressure is very low it seems probable that the substances present in this water are in a colloidal state. The above data tend to confirm this view and suggest that the colloidal matter may be a large factor in the toxicity of bog waters.

The waters used were obtained from sphagnum bogs in the Puget Sound region and Alaska.

George B. Rigg

University of Washington

EXHIBITION OF THE ROYAL PHOTOGRAPHIC SOCIETY

To the Editor of Science: The sixty-first annual exhibition of the Royal Photographic Society will be held as usual in August and September of this year. In order to facilitate the collection and forwarding of scientific exhibits I have been appointed one of the judges in the scientific section of the forthcoming exhibition and have made arrangements to receive photographs from American workers and to forward them to London, thus relieving the photographer of all difficulty and expense.

I should be very glad to hear from any American photographer who wishes to enter photographs in the scientific section of the exhibition of the Royal Photographic Society and to forward him an entry form.

For some years now the American exhibit in the scientific section has been a comprehensive one and of great interest to European workers

as showing what has been done on this side of the Atlantic, and it is earnestly desired by the council of the Royal Photographic Society that the United States should continue to be fully represented in this exhibition.

C. E. K. MEES

KODAK PARK,
ROCHESTER, N. Y.

THE CARNEGIE FOUNDATION

THE president of the Carnegie Foundation for the Advancement of Teaching has printed and distributed a long discussion of the policies of the foundation. Although this has been sent to thousands of teachers it is curiously, but characteristically, marked "Confidential." As it can not be discussed directly, the writer has reprinted the articles on the subject which appeared in SCIENCE several years ago and will be glad to send a copy to any reader of this note who may care to ask for it. It is desirable at least to watch the Greeks, both when they bear gifts and when they take them away.

J. MCKEEN CATTELL

GARRISON-ON-HUDSON, N. Y.,
April 15, 1916

SCIENTIFIC BOOKS

The Telephone and Telephone Exchange, Their Invention and Development. By J. E. KINGSBURY, M.I.E.E. Longmans Green & Co. 1915. Cloth. 558 pages, 170 illustrations. Price $4.00 net.

Considering that the telephone, in its serviceable form, is an American invention; that the telephone switchboard and exchange were first developed in America, and that the number of telephones per unit of population is much greater in America than in any other part of the world, it is remarkable that this is the first book that pretends to give a comprehensive outline of the history of telephonic development, and that this first book should have been written in England. This is an index of the general condition of inventors, engineers and engineering, all the world over. As a body, engineers are rarely gifted with talents for literature, or for historical research; yet collectively, they have transformed the surface of this planet, and have revolutionized its modes of living. However, if one should ask of a local resident near some monumental structure, grand bridge, or imposing viaduct, as to who erected it, the answer would be likely to be limited to the name of a capitalist.

This book traces very entertainingly the development of the Bell telephone, from its early conception in the mind of the inventor, to the standard instrument on so many a table of to-day. The author modestly disavows the title "history" for his book. Nevertheless, a very large amount of historical research must have been carried on by him, in order to make up the interesting narrative contained in these pages.

The following list of chapter headings will convey an idea of the scope of the historical work: Introductory, The spoken word, The growth of an idea, The undulatory current, The solution of the problem, Development and demonstration, The production of a commercial instrument, The application to commercial uses, The telephone exchange, The battery or variable-resistance transmitter, The microphone, Philipp Reis and his work, Call bells, The telephone switchboard, The organization of the industry in the United States, Competition, Consolidation and development, Introduction of the telephone in Europe and abroad, Public apathy and appreciation, The multiple switchboard, Outside or line construction, Ten years' progress, The Development of dry-core cable, Early exchange systems, Telephone engineering on a scientific basis, The branching system, The common-battery system, Automatic and semi-automatic switchboards, Long-distance service, Instruments, Rates, The economics of the telephone, The telephone and governments, Conclusion.

The task of considering the invention and development of each individual element in a modern telephone system is a very difficult one. There are so many claimants, and their claims are so antagonistic. The author has carried out this task in his own way, and with a fairmindedness that merits approbation. It

may be urged that, in America, he has not done full justice to the work of the independent telephone companies and their inventors. The great bulk of the development in this country is undoubtedly due to the Bell organization, its pioneers, inventors, organizers, engineers and constructors; yet a very appreciable residual share is due to the competing independent companies. It must be remembered, however, that the author has not had the same opportunity to become acquainted with ultra-Bell sources in America, that he has in Great Britain, but there he has given credit with an impartial pen.

The chapter on the telephone and governments should be studied by those who, as outsiders in telephony, seek to form a just estimate of the relative advantages of governmental versus private-corporation administration. The author knows whereof he speaks, for he has been in intimate touch with telephony in England, both under company operation, and under government operation. He also writes in a fair and open-minded vein. The conclusion which is apparently unavoidable is that governments are not able to operate a country's telephone system so efficiently, economically or progressively as a private corporation under government control. For this conclusion, there is certainly abundant evidence. In Europe, where the governments almost invariably operate the systems, the only country in which it appears that the telephones are in private hands, is Denmark. Denmark is accorded 4.5 telephones per hundred of population; whereas the highest use in any government-operated country is 2.1 (for the German Empire). In the United States, the number given is 9.7 per hundred, or more than double Denmark's.

The book is almost the only history of its kind, and is a welcome addition to the literature of telephonic growth and development.

A. E. Kennelly

An Introduction to the Principles of Physical Chemistry. By Edward W. Washburn. New York, McGraw-Hill Book Co., Inc., 1915. Pp. xxv + 445.

This volume constitutes a marked departure from the conventional method of treatment which most authors have followed under the influence of the early spirit of physical chemistry which found concrete expression in Ostwald's "Lehrbuch der allgemeinen Chemie." Many years have elapsed since this epoch-making work appeared and many important contributions have been made to our knowledge of the subject in the meantime. The controversies, however, which arose in the early development of physical chemistry, have been so prolonged that most writers have confined themselves to the outline of the subject as established by precedent and have found little opportunity to lay before the student the more recent developments in this field. In this respect the present volume is a welcome addition to the literature. The treatment of the subject is distinctly along original lines.

The book is well written, and the subject-matter is presented in a manner which retains the interest of the reader. A large number of very excellent figures are given, many of them being original. The numerous problems appearing throughout the text are well selected. The biographical references will prove of interest to the student. A later edition should give reference, however, to Mayer, Joule and Helmholtz, in connection with the first law of thermodynamics. The reference to J. Willard Gibbs as "one of America's greatest chemists," fails to recognize the importance of Gibbs's work along other lines than those of chemistry. References to the literature are numerous and add greatly to the value of the text. Cross references are frequent, but references to page and section would be more convenient than references to chapter and section. Misprints and other minor defects are much less common than is usual in first editions.

The division of the subject-matter is excellent, on the whole, but it is to be noted that the greater portion of electrochemistry is omitted. Gaseous equilibria, in fact, equilibria in general, with the exception of electrolytic equilibria, are treated very briefly. The Nernst heat theorem is not mentioned, al-

though specific heats are discussed at some length.

Nearly all of the important physical chemical relationships are expressed in mathematical form. The derivation of those relationships which are based on thermodynamic principles is given in an appendix. The differential equations are obtained by means of an ingenious device termed a "Perfect Thermodynamic Engine," which appears to be a modification or rather an amplification of the familiar cyclic process. This method of treatment should be of great service to those students who lack the analytical turn of mind.

As stated in his preface, the author has made a radical departure from the classical treatment of the second law of thermodynamics. He has attempted to formulate this law in mathematical form by means of elementary kinetic considerations. The Carnot cycle has been entirely omitted. The wisdom of this procedure may be questioned, for the method involving Carnot's cycle is both simple and instructive. It brings out, moreover, the important fact that the second law is a principle of that general character which is not dependent upon the mechanism involved in a given process, and that conversely it can give us no information as to the character of the mechanism involved therein. The necessity of supplementing thermodynamics with results obtained from the kinetic hypothesis is thus almost self-evident, but it is well to avoid leading the student to infer that simplicity is one of the chief virtues of the statistical method. The author's argument on pages 104 and 105 is not over clear. The two processes there described are not identical as to initial and final conditions, nor is it apparent how these two processes are related to each other. The treatment given tends to confuse the work of a Carnot's cycle with the second law of thermodynamics, while it does not clearly point out that the second law involves an inequality, not an equality. The entropy function, which is of fundamental importance in the treatment of the second law, is nowhere mentioned, nor is the Helmholtz equation formulated.

The subject of solutions is treated at length and from a much more general point of view than is commonly the case. Electrolytic solutions, so far as aqueous solutions are concerned, are fully treated. An excellent discussion is given of equilibria involving the ions of water, including hydrolytic and indicator reactions.

In treating the phase rule the author introduces the composition number, which is the mol-fractions of the smallest number of molecular species present in a given phase which must be specified in order to fix the composition of the phase in question. The composition number of a system is defined as "equal to the largest composition number of any of the phases of the system." The last definition leads to a certain restriction of the phase rule which is avoided in the usual method of treatment. This becomes clear in the case of a two component system in which the three phases present in equilibrium are all pure substances, as, for example, in the system, $CaCO_3$, CaO, CO_2. The author's definition leads to the necessity of considering that one of the phases contains all of the substances in question, for example, that the vapor phase contains $CaCO_3$ and CaO as well as CO_2.

In the discussion of the composition-temperature diagram of solid solutions (p. 356), the author has failed to give the interpretation of the field lying between the curves for the solid and liquid solutions. A few other minor corrections may be noted. The definition of the viscosity coefficient (p. 51) is in error; the maximum work is not clearly distinguished from the free energy (p. 110); the terms "divariant" and "binary," "trivariant" and "ternary," etc., are confused with each other (p. 342).

The book comprises 27 chapters and an appendix, and covers the entire field with the exceptions noted above. It is only in exceptional instances that anything but the most favorable criticism can be made. The author has made an important contribution to the list of texts available for the use of students. The volume should find its way generally into the chemist's library. In the hands of a compe-

tent instructor it should prove an admirable text for classroom use.

Charles A. Kraus

Clark University,
March, 1916

Being Well-Born: An Introduction to Eugenics. By Michael F. Guyer, Ph.D. Indianapolis, The Bobbs-Merrill Co., 1916. 374 pages. $1.00.

This is one of the later volumes in the extensive "Childhood and Youth Series" edited by M. V. O'Shea. The general purpose of this series is "to give to parents, teachers, social workers and all others interested in the care and training of the young, the best modern knowledge about children in a manner easily understood and thoroughly interesting." The special purpose of this volume is "to examine into the natural endowment of the child" and to give "an account of the new science of eugenics." There is some reason for thinking that the value of Professor Guyer's work would not have been lessened, had he been entirely freed from the special purposes and influences of the "Series." As it stands, however, the work has very distinct merit and a high degree of usefulness.

In its general plan the book does not differ materially from other "Introductions" to the hybrid science of eugenics, although certain phases are treated with more than the usual detail. The work may be divided into three parts. The first, including the first four chapters, deals with the subject of heredity, its definition, cytological basis and Mendelian descriptions. This is the clearest cut and most authoritative section, well adapted for the student class. The reviewer's experience, however, leads him to believe that the average reader of the class for whom it is intended, will find even these clear descriptions too difficult really to be comprehended without the added services of an experienced guide. The glossary which is appended will aid in assisting the uninitiated over the difficult spots. The attempt to explain the inheritance of sex and of sex-linked characters, before the principles of Mendelism have been discussed is unusual. It is of interest to note that, wisely, only four pages are given to the statistical descriptions of heredity, and that the author takes a conservative position regarding the Mendelian interpretation of some of the data from the Eugenics Record Office.

The second group of four chapters sets forth some of the implications of the facts described in the first section, as they are related to the characteristics of the individual. Two long chapters entitled "Are Modifications Acquired Directly by the Body Inherited" and "Prenatal Influences" are certain to be of very great value to the general reader. The materials are well considered, lucidly presented and a clear distinction made between the scientific and the superstitious conceptions of prenatal influence. This is a subject upon which popular ideas seem hopelessly confused and Professor Guyer has done well to devote so much space to their consideration. The chapter on "Responsibility for Conduct" is less direct and logical, leaving the reader in some doubt as to whether the author's conclusion that "All normal men are responsible for their conduct" is the only one that could be drawn from the evidence given. This is the least satisfactory chapter in the book.

The last section consists of two chapters dealing with the social implications of the facts of heredity. There are very clear and pointed summaries of what is known and of what is believed in this field. The euthenic aspects of the problem are stated and fully credited and the whole discussion is well tempered and sane. Finally the familiar remedies for correcting the antisocial and degenerative process now going forward at so rapid a pace, are discussed. Marriage restrictions and mating systems are recognized as of relatively little practicality; segregation is regarded as hopeful though costly; sterilization as still on trial. Public education and the ensurance of environments that will call forth right reactions seem to offer, for the present, the most hopeful elements in the eugenic program.

The book is well got up, unusually free from errors and the price remarkably low, all of which will add to its well-deserved usefulness and influence.

Wm. E. Kellicott

NOTES ON CANADIAN STRATIGRAPHY AND PALEONTOLOGY. I

Cordilleran Province

IN 1911 and 1912 Dr. R. A. Daly carried on geological studies along the line of the Canadian Pacific railway between Golden and Kamloops, British Columbia, a distance of 224 miles. A preliminary statement of results was published in Guide Book No. 8 of the International Geological Congress and the complete report has recently become available.[1] The transverse section of the eastern half of the Canadian Cordillera thus made known roughly parallels the International Boundary section and is about 120 miles north of it.

Three major geological provinces are recognized. The first of these is that underlain in the main by the Shuswap terrane and includes a portion of the Selkirks and the northern half of the Columbia mountains. The Shuswap rocks are of "Early Pre-Cambrian" age and consist of metamorphosed sediments and volcanics, aggregating over 28,000 feet in thickness, intruded by innumerable sills and laccoliths of granite as well as by batholithic masses of the same plutonic rock. The whole is essentially a very large mass of ideal crystalline schists, the result of static metamorphism. The author very properly makes a distinction between recrystallization which results from deep burial and that accompanying orogenic movement. The former he terms static or load metamorphism, restricting the term dynamic metamorphism to the latter phase. In the alteration of the Shuswap terrane both contact and dynamic metamorphism have played minor parts.

Unconformably overlying the Shuswap schists on the east is an enormous mass of bedded rocks belonging to the Beltian and Cambrian systems. These make up the greater part of the Purcell and higher Selkirk mountains. The Belt series consists of quartzites, limestones, and metargillites attaining a thickness of 32,750 feet and is overlain by 7,750 feet of quartzite referred to the lower Cambrian. No evidence of unconformity between the Beltian and Lower Cambrian was observed. The clastic sediments of these series were derived in the main from the erosion of the Shuswap terrane. The absence of ripple marks and mud cracks leads to the conclusion that most of the Beltian-Cambrian sediments in the region traversed are off-shore deposits. No horizons of playa or flood-plain sediments were identified. Much of the finer quartz silts are believed to have originated as wind-borne dust, blown out to sea. The limestones are interpreted as chemical precipitates resulting from the bacterial decay of animal matter. Extrusive lavas are in some places interbedded with the sediments. The entire series has been moderately metamorphosed and its structure is that of a great synclinorium nearly forty miles broad. East of the Purcell range the Columbia River valley is believed to be underlain by Upper Cambrian and Ordovician beds which have been faulted into contact with the Beltian formations.

West of the Shuswap terrane, Beltian and early Paleozoic rocks are absent, and the upper Paleozoic and younger formations are believed to rest on the pre-Cambrian complex. This constitutes the province of the Interior Plateaus. Its geology is allied to that of the Coast and Vancouver ranges as it is in the western geosynclinal belt of the Cordillera, which forms a strong contrast to the eastern belt. Until the close of Mississippian time the western belt was in the main a land surface, while in the eastern belt sedimentation was in progress. Structural complexity here is of a high order. At the base is the Cache Creek series, 13,700 feet of limestone and clastic sediments, of probably Pennsylvanian age. Unconformably overlying this series are the conglomerates, breccias, sandstones, and massive lavas of the Nicola series. This has an estimated thickness of 5,300 feet and is referred to the Triassic and Jurassic periods. The youngest bed-rock formation in the area is a thick mass of Tertiary volcanics with interbedded sediments, which is believed to be of Oligocene age.

[1] "A Geological Reconnaissance between Golden and Kamloops, B. C., along the Canadian Pacific Railway," R. A. Daly, Geological Survey, Canada, Memoir 68, 1915.

Another important contribution to Cordilleran stratigraphy is that of Dr. S. J. Schofield.[2] Intensive studies of a large portion of the Purcell range south of the Canadian Pacific railway have been carried on for a period of five years. The area mapped includes about 2,500 square miles immediately north of the International Boundary, but the problems encountered involved reconnaissance work extending over much greater areas. The region includes a part of the section traversed by Dr. Daly in 1901 to 1906 and discussed by him in his report upon the geology of the Forty-ninth Parallel.[3] The detailed examinations of the more recent survey make necessary a number of changes in the somewhat tentative correlations and structure determinations of the earlier reconnaissance work.

The bed-rock of the Cranbrook area may be referred to two systems. By far the greater part belongs to the Belt terrane which is unconformably overlain by remnants of Devono-Carboniferous limestones. Neither the base nor the summit of the Beltian system, as determined in the Rocky Mountains, is exposed in the Purcell range. The Purcell series is composed of 22,500 feet of sediments, largely clastic, which by their numerous horizons of mud cracks, ripple marks, casts of salt crystals, and red beds suggest a continental rather than marine origin for most of the strata. Near the top of the series are recurrent basaltic flows whose extrusion was accompanied by the intrusion of gabbro sills. Probably the most significant departure from Dr. Daly's conclusions is that relative to the age of the uppermost of the Purcell formations. In the Forty-ninth Parallel report nearly 11,000 feet of strata were regarded as of Lower and Middle Cambrian age. The later survey has resulted in determining that the entire series is of pre-Cambrian age and that the uppermost beds were deposited some time before the close of Proterozoic times.

Throughout the entire Paleozoic and Mesozoic eras, with the exception of the interval during which marine limestones of Devonian and Mississippian age were deposited, the region seems to have been subject to erosion. Orogenic movements, possibly at the close of the Jurassic period, formed a great series of anticlines and synclines and were followed or accompanied by intrusions of granite bosses and batholiths. Subsequently erosion reduced the area to an old-age topography, which was later uplifted and is now represented by the summit levels of the mountain range. Here, again, Dr. Schofield differs from Dr. Daly, who attempted to explain the present topography in terms of one-cycle erosion. From the excellent illustrations accompanying the report, as well as from the facts cited, the reviewer would agree with the author of the recent memoir. However, the reference of the peneplain to the Cretaceous period does not seem to be justified by the meager data available. The present topography may well have been developed by the dissection of the graded surface since late Tertiary times. A study of the relations of the summit peneplains of the adjacent ranges to the mid-Tertiary lavas of the Interior Plateaus should yield evidence enabling the determination of the dates of rejuvenation.

Quaternary deposits include fossiliferous sands and gravels overlain by glacial drift. The former are presumably of interglacial age and indicate a climate as warm as that of the southern United States at the present time. These are found in the Rocky Mountain Trench, a topographic feature extending from the International Boundary northward into Alaska, which is believed to be the result of erosion controlled by fault planes.

Paleozoic Strata of Central Canada

The "Hudson Bay Exploring Expedition" of 1912, under the leadership of J. B. Tyrrell, secured collections of fossils from the little-known region which forms the southern shore of Hudson bay. The collections include a large number of fossils from the Silurian outcrops along the Severn and Fawn rivers as well as certain Ordovician species from the region southeast of Port Nelson in northern Manitoba. These have been described recently by

[2] "Geology of Cranbrook Map-Area, British Columbia," S. J. Schofield, Geological Survey, Canada, Memoir 76, 1915.

[3] Geological Survey, Canada, Memoir 38, 1913.

Dr. W. A. Parks,[4] who recognizes among them 132 distinct forms. Of these 48 are ascribed to known species and 31 are new to science. Gastropods and cephalopods, some of which are of unusually robust proportions, predominate. The general aspect of the Silurian fauna indicates a horizon comparable with the Guelph, while the Ordovician species suggest the fauna of the Trenton.

The upper portion of the Lockport member of the Niagara formation in Ontario is a thin-bedded bituminous dolomite with intercalations of shale. These beds ordinarily attain a thickness of thirty to forty feet, and Dr. M. Y. Williams, who has recently discovered in them an eurypterid horizon,[5] proposes for them the name "Eramosa beds." The eurypterid, a new species of *Eusarcus,* was found near Guelph, Ontario, associated with several brachiopods, a bryozoan, and two species of *Conularia.* The fauna presents a typically Lockport facies, but contains recurrent Rochester forms as well as a single prenuncial Guelph form. The association of the eurypterid with a purely marine fauna is suggestive of a marine habitat for the former, but, contrary to the author's statement, does not necessarily prove such an environment. Such an association might result if non-marine arachnids were washed down a river to the salt waters at its debouchure. Apparently all the specimens of *Eusarcus* are in this instance fragmentary.

For a number of years the Devonian formations and faunas of the western peninsula of Ontario, between Lakes Huron and Erie, have been under investigation by Dr. C. R. Stauffer, whose final report has become available.[6] The formations studied may be arranged in tabular form as follows:

Devonian	Upper	Portage-Chemung?	Port Lambton beds.
		Genesee?	Huron shale.
	Middle	Hamilton	Ipperwash limestone. Petrolia shale. Widder beds. Olentangy shale.
		Marcellus	Delaware limestone.
		Onandaga	Onandaga limestone. Springvale sandstone (local facies).
	Lower	Oriskany	Oriskany sandstone.
		Helderberg	wanting, or possibly represented, in part, by the Detroit River series.

The Detroit River series is an eastern extension of the Upper Monroe of Michigan and little light is thrown upon the problem of its correlation. Its fauna in Ontario indicates the same curious mingling of late Silurian and mid Devonian elements which characterizes its occurrence in southern Michigan.[7] Dr. Stauffer apparently favors the reference of the group to the Upper Silurian, but closes his discussion with the statement that it is the "official practise of the Canadian Geological Survey" to treat these beds as part of the Devonian system.

The Oriskany sandstone is separated from subjacent and superjacent beds by unconformities and is believed to be identical in age with the formation of the same name in New York state. Its fauna is distinctly a southern and eastern one, and there is no evidence in

[4] "Palaeozoic Fossils from a Region Southwest of Hudson Bay," W. A. Parks, *Trans. Roy. Can. Inst.*, Toronto, Vol. XI., 1915, pp. 1–96.

[5] "An Eurypterid Horizon in the Niagara Formation of Ontario," M. Y. Williams, Geological Survey, Canada, Museum Bulletin No. 20, 1915.

[6] "The Devonian of Southwestern Ontario," C. R. Stauffer, Geological Survey, Canada, Memoir 34, 1915.

[7] Grabau, A. W., and Sherzer, W. H., Mich. Geol. and Biol. Surv., Pub. 2, Geol. Ser. 1, 1910, pp. 217–221.

support of the supposed mingling of Oriskany and Onandaga faunas at this place. That conception seems to have resulted from the failure to discriminate the lithologically similar Springvale sandstone which is in reality a local facies of the Onandaga.

The Onandaga fauna is composed of three important elements. Many forms lingered over from the Oriskany of this general region. Others seem to be related to the inhabitants of the Lower Devonian embayment of southern Illinois. The most distinctive element is that including the corals; it bears such marked relationship to contemporaneous European faunas as to indicate a shallow-water connection with that continent. The line of migration was probably, as suggested by Weller some years ago, via the Arctic regions and James Bay.

The Delaware limestone of Ontario is essentially the western equivalent of the Marcellus shale of New York. Its fauna is transitional between those of the Onandaga and Hamilton.

The Hamilton fauna is much the same in Ontario as in New York. In the main it is a derivation from the Onandaga fauna but it also contains many immigrants from South America. In one locality the Hamilton rocks are largely limestone and there the resemblance of its fauna to that of the Onandaga is very close.

The Upper Devonian strata are for the most part heavily drift covered and known only from well records. The worms and lingulas of the black shale, correlated with the Huron of Ohio, indicate its contemporaneity with the Genesee of New York. Nothing is known of the fauna from the green shales of the Port Lambton beds.

Quaternary Geology

In the region adjoining the International Boundary between Rainy Lake and Lake of the Woods, unconsolidated deposits of Quaternary age overlie the pre-Cambrian crystalline rocks. The study[8] of the surficial sediments has revealed the presence of a single small remnant of leached and weathered till deposited by probably pre-Wisconsin ice advancing from the Keewatin center. It is overlain by drift, reddish where weathered, but ordinarily gray in its lower portion, which was deposited over the whole region by ice of the Wisconsin stage moving southwestward from Labrador. Shortly after the retreat of this ice the district was invaded from the northwest by the Keewatin ice sheet of the same stage, which deposited calcareous till and boulder-clay and formed a marginal glacial lake. The latter was enlarged as the ice margin withdrew and glacio-lacustrine clays conceal the till over large areas. The clays show seasonal lamination and the reviewer infers from the author's statements that this "Early Lake Agassiz" existed for about 750 years after the withdrawal of the ice before its waters were drained. An interval, sufficiently long to permit of extensive weathering and the establishment of drainage systems, followed the disappearance of this lake and then the region was gradually transgressed by the waters of Lake Agassiz. These advanced southward with increasing depth of the lake as the northward-flowing streams were ponded by a slight re-advance of the Labrador ice sheet. The lacustrine sands, gravels, and clays are overlain by Recent deposits of wind-borne sediment and the peat and swamp muck which filled shallow depressions in the lake floor after its waters had drained away.

A less complex series of Quaternary deposits form the surficial materials of the Island of Montreal.[9] Boulder-clay covers the pre-Cambrian and early Paleozoic rocks nearly everywhere on the island and is in some places overlain by the Leda clay and Saxicava sands. Only one drift sheet, the Wisconsin, has been identified. The clays and sands are deposits in an arm of the sea which occupied the St. Lawrence valley during the "Champlain substage" immediately following the retreat of the Labrador ice sheet. Both formations con-

[8] "The Rainy River District, Ontario, Surficial Geology and Soils," W. A. Johnston, Geological Survey, Canada, Memoir 82, 1915.

[9] "The Pleistocene and Recent Deposits of the Island of Montreal," J. Stansfield, Geological Survey, Canada, Memoir 73, 1915.

tain an abundant fossil fauna, largely of marine molluscs. The Saxicava formation includes beach gravels which are found at 27 different levels of general importance so far as the island is concerned. The highest of these is at an altitude of 617 feet above tide. Post-glacial movements are represented by minor faults and folds as well as by the continental deformation which altered the shore-lines of the Champlain sea. The latter is attributed to isostatic adjustment consequent upon the removal of the ice-load.

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SPECIAL ARTICLES

THE THEORY OF THE FREE-MARTIN

THE term free-martin is applied to the female of heterosexual twins of cattle. The recorded experience of breeders from ancient times to the present has been that such females are usually barren, though cases of normal fertility are recorded. This presents an unconformable case in twinning and sex-determination, and it has consequently been the cause of much speculation.

The appearance of an abstract in SCIENCE[1] of Leon J. Cole's paper before the American Society of Zoologists on "Twinning in Cattle with Special Reference to the Free-Martin," is the immediate cause of this preliminary report of my embryological investigation of the subject. Cole finds in a study of records of 303 multiple births in cattle that there were 43 cases homosexual male twins, 165 cases heterosexual twins (male and female), and 88 cases homosexual female, and 7 cases of triplets. This gives a ratio of about 1♂♂ : 4♂♀ : 2♀♀, for the twins instead of the expected ratio of 1:2:1. Cole then states:

> The expectation may be brought more nearly into harmony with the facts if it is assumed that in addition to ordinary fraternal (dizygotic) twins, there are numbers of "identical" (monozygotic) twins of both sexes, and that while in the case of females these are both normal, in the case of a dividing male zygote, to form two individuals, in one of them the sexual organs remain in the undifferentiated stage, so that the animal superficially resembles a female and ordinarily is recorded as such, although it is barren. The records for monozygotic twins accordingly go to increase the homosexual female and the heterosexual classes, while the homosexual male class in which part of them really belong, does not receive any increment.

Cole thus tentatively adopts the theory, which has been worked out most elaborately by D. Berry Hart, stated also by Bateson, and implied in Spiegelberg's analysis (1861), that the sterile free-martin is really a male co-zygotic with its mate.

Cole's figures represent the only statistical evidence that we have on this subject. Let us follow his suggestion and take from the heterosexual class enough cases to make the homosexual male twins equal in number to the homosexual female pairs; this will be approximately one fourth of the class, leaving the ratio 2:3:2 instead of 1:4:2. Which one of these is the more satisfactory sex ratio I leave others to determine; I wish only to point out the fatal objection, that, according to the hypothesis, the females remaining in the heterosexual class are normal; in other words, on this hypothesis the ratio of normal free-martins (females co-twin with a bull) to sterile ones is 3:1; and the ratio would not be very different on any basis of division of the heterosexual class that would help out the sex ratio. Hitherto there have been no data from which the ratio of normal to sterile free-martins could be computed, and Cole furnishes none. I have records of 21 cases statistically homogeneous, 3 of which are normal and 18 abnormal. That is, the ratio of normal to sterile free-martins is 1:6 instead of 3:1.

This ratio is not more adverse to the normals than might be anticipated, for breeders' associations will not register free-martins until they are proved capable of breeding, and some breeders hardly believe in the existence of fertile free-martins, so rare are they.

My own records of 41 cases of bovine twins (to date, February 25, 1916), all examined *in utero,* and their classification determined anatomically without the possibility of error,

[1] Vol. XLIII., p. 177, February 4, 1916.

give 14♂♂ : 21♂♀ : 6♀♀. It will be observed that this agrees with expectation to the extent that the sum of the homosexual classes is (almost) equal to the heterosexual class; and it differs from expectation inasmuch as the ♂♂ class is over twice the ♀♀ class instead of being equal to it, as it should be if males and females are produced in equal numbers in cattle. The material can not be weighted statistically because every uterus containing twins below a certain size from a certain slaughter house is sent to me for examination without being opened. Cole's material shows twice as many female as male pairs, and the heterosexual class is about one third greater than the sum of the two homosexual classes. I strongly suspect that it is weighted statistically; the possibility of this must be admitted, for the records are assembled from a great number of breeders. But, whether this is so or not, if we add the sterile free-martin pairs of my collection to the male side in accordance with Cole's suggestion, we get the ratio 32♂♂ : 3♂♀ : 6♀♀, which is absurd. And if we take Cole's figures, divide his heterosexual class into pairs containing sterile females and pairs containing normal females according to the expectation, 6 of the former to 1 of the latter, and add the former to his male class, we get an almost equally absurd result (184♂♂ : 23♂♀ : 88♀♀). On the main question our statistical results are sufficiently alike to show that the free-martin can not possibly be interpreted as a male. The theory of Spiegelberg, D. Berry Hart, Bateson and Cole falls on the statistical side alone.

But the real test of the theory must come from the embryological side. If the sterile free-martin and its bull-mate are monozygotic, they should be included within a single chorion, and there should be but a single corpus luteum present. If they are dizygotic, we might expect two separate chorions and two corpora lutea. The monochorial condition would not, however, be a conclusive test of monozygotic origin, for two chorions originally independent might fuse secondarily. The facts as determined from examination of 41 cases are that about 97.5 per cent. of bovine twins are monochorial, but in spite of this nearly all are dizygotic; for in all cases in which the ovaries were present with the uterus a corpus luteum was present in each ovary; in normal single pregnancies in cattle there is never more than one corpus luteum present. There was one homosexual case (males) in which only one ovary was present with the uterus when received, and it contained no corpus luteum. This case was probably monozygotic.

There is space only for a statement of the conclusions drawn from a study of these cases, and of normal pregnancies. In cattle a twin pregnancy is almost always a result of the fertilization of an ovum from each ovary; development begins separately in each horn of the uterus. The rapidly elongating ova meet and fuse in the small body of the uterus at some time between the 10 mm. and the 20 mm. stage. The blood vessels from each side then anastomose in the connecting part of the chorion; a particularly wide arterial anastomosis develops, so that either fetus can be injected from the other. The arterial circulation of each also overlaps the venous territory of the other, so that a constant interchange of blood takes place. If both are males or both are females no harm results from this; but *if one is male and the other female, the reproductive system of the female is largely suppressed, and certain male organs even develop in the female. This is unquestionably to be interpreted as a case of hormone action.* It is not yet determined whether the invariable result of sterilization of the female at the expense of the male is due to more precocious development of the male hormones, or to a certain natural dominance of male over female hormones.

The results are analogous to Steinach's feminization of male rats and masculinization of females by heterosexual transplantation of gonads into castrated infantile specimens. But they are more extensive in many respects on account of the incomparably earlier onset of the hormone action. In the case of the free-martin, nature has performed an experiment of surpassing interest.

Bateson states that sterile free-martins are found also in sheep, but rarely. In the four

twin pregnancies of sheep that I have so far had the opportunity to examine, a monochorial condition was found, though the fetuses were dizygotic; but the circulation of each fetus was closed. This appears to be the normal condition in sheep; but if the two circulations should anastomose, we should have the conditions that produce a sterile free-martin in cattle. The possibility of their occurrence in sheep is therefore given.

The fertile free-martin in cattle may be due to cases similar to those normal for sheep. Unfortunately when the first two cases of normal cattle free-martins that I have recorded, came under observation I was not yet aware of the significance of the membrane relations, and the circulation was not studied. But I recorded in my notebook in each case that the connecting part of the two halves of the chorion was narrow, and this is significant. In the third case the two chorions were entirely unfused; this case, therefore, constitutes an *experimentum crucis*. The male was 10.4 cm. long; the female 10.2 cm. The reproductive organs of both were entirely normal. The occurrence of the fertile free-martin is therefore satisfactorily explained.

The sterile free-martin enables us to distinguish between the effects of the zygotic sex-determining factor in mammals, and the hormonic sex-differentiating factors. The female is sterilized at the very beginning of sex-differentiation, or before any morphological evidences are apparent, and male hormones circulate in its blood for a long period thereafter. But in spite of this the reproductive system is for the most part of the female type, though greatly reduced. The gonad is the part most affected; so much so that most authors have interpreted it as testis; a gubernaculum of the male type also develops, but no scrotal sacs. The ducts are distinctly of the female type much reduced, and the phallus and mammary glands are definitely female. The general somatic habitus inclines distinctly toward the male side. Male hormones circulating in the blood of an individual zygotically female have a definitely limited influence, even though the action exists from the beginning of morphological sex-differentiation. A detailed study of this problem will be published at a later date.

FRANK R. LILLIE

UNIVERSITY OF CHICAGO

A CHEMOTROPIC RESPONSE OF THE HOUSE FLY (MUSCA DOMESTICA L.)[1]

IT is generally conceded that the house fly lays its eggs most frequently in fermenting vegetable substances. Of these, fermenting horse manure is most often chosen, and about cities probably ninety per cent. or more of the house flies are bred from this substance.[2]

Although manure varies considerably, depending upon the food, the age and the health of the horse, it seems to be invariably attractive to female house flies, provided it is moist and not very old. The flies come to the manure primarily to lay their eggs, and although they may obtain some food from it, this is only a secondary object.

These general observations, together with some preliminary studies recently published,[3] led me to believe that the house fly was allured to the manure pile by the odor of some volatile chemical substance which was liberated during the early stages of fermentation. Acting on this hypothesis, I have tested during the past summer the response of the house fly to a number of inorganic and organic compounds which occur as products of fermentation in barnyard manures.

This paper is a preliminary statement of the results of these experiments. A more detailed account will be given in another place.

Trap Experiments with Ammonia and Other Chemical Substances

The following chemical compounds were exposed in glass containers in screen-wire-fly

1 This work was done in the department of entomology, New Jersey Agricultural College Experiment Station, and is published by permission of Dr. T. J. Headlee, entomologist of that station.

2 Howard, L. O., "The House Fly—Disease Carrier," New York, 1911, p. 7.

3 27th Ann. Rpt. N. J. Agr. College Exp. Station, 1914, pp. 396–399.

traps, 9¾ inches high, and 6 inches in diameter at the base: Ammonium carbonate U. S. P. (contained about 97 per cent. of ammonium acid carbonate and ammonium carbamate), ammonium sulphide solution, ammonium hydroxide, ethyl alcoholic solutions of skatol and indol, ethyl alcohol, acetic, formic, butyric and valerianic acids, hydrogen sulphide solution and carbon dioxide. The traps which volatilized carbon dioxide were equipped with Erlenmeyer flask droppers, which delivered dilute hydrochloric acid a drop at a time on to bits of limestone in the pan of the trap. By this method a small but fairly constant amount of carbon dioxide was evolved throughout a number of hours. A trap was similarly equipped for use in the ammonium hydroxide experiment.

The experiments were performed at a place where flies were always present, but never excessively abundant.

Negative results were obtained in all but the ammonium hydroxide and ammonium carbonate experiments. The results of ten ammonium carbonate trap experiments are summarized below.

Material Used in Each Trap	Number of Traps	Duration of Experiments	Number of Flies Caught			
			Males	Females	Sex Undetermined	Total
Ammonium carbonate, 85–234 gm., and water (50–90 c.c.) or without water.	23	51–220 hrs.	16	186	3	205
Control, with or without water (50–90 c.c.)...	17	51–220 hrs.	5	3	4	12

House flies were attracted to the traps which contained ammonium carbonate. Small amounts of water and carbon dioxide, both constituents of ammonium carbonate, were not sought by flies, and it is concluded that the other constituent, ammonia, was the attracting agent.

The best results were obtained when water was added to the ammonium carbonate, because it prevented the deposit of a powdery layer of the less volatile ammonium acid carbonate which otherwise hindered the escape of ammonia.

The single ammonium hydroxide trap caught three female house flies during twenty-five hours' exposure.

Since the flies caught in the ammonium carbonate traps were largely females (90.7 per cent.), it was desired to know whether ammonia was particularly attractive to females, or whether females were unusually abundant in the vicinity of the experiments. Under ordinary conditions remote from breeding places the proportion of sexes in the house fly is about equal, with a slight excess of females.[4]

Accordingly, traps baited with food materials (milk, sweet soda water), were maintained in the vicinity of the ammonium carbonate experiments from July 21 to July 29. During this time 274 house flies were captured, 45.9 per cent. of which were males, and 54.0 per cent. females. In the same period, the ammonium carbonate traps caught 65 flies, 7.6 per cent. males and 89.2 per cent. females. Ammonia attracted a great preponderance of females.

Oviposition Experiments

Acidulated horse manure, timothy chaff, pine sawdust, and cotton were treated in such a way that they evolved ammonia. They were then exposed in a place frequented by flies, and after a period which varied from 3 to 99 hours in the individual experiments, counts were made of the egg-masses which had been deposited. Two or more eggs, placed together, were considered an egg-mass, but the large majority of clusters contained many more than two eggs. Occasional single eggs were ignored.

Oviposition in Acidulated Horse Manure.—The purpose of this series of experiments was to show whether fresh horse manure which did not volatilize ammonia would still induce the house fly to oviposit, and whether such manure, when again volatilizing ammonia, would attract the female fly. Fresh horse manure was treated with dilute hydrochloric acid so that

[4] Hewitt, "The House Fly (*Musca domestica* L.)," etc., Cambridge, England, 1914, p. 98.

the free ammonia was converted into ammonium chloride, an involatile salt at the ordinary temperature. The manure was left in a slightly acid state so that all the ammonia formed during the course of the experiments would immediately unite with the acid. It was tested with litmus paper for acidity before and after each experiment.

Porcelain evaporating dishes 120 mm. in diameter and 35 mm. deep were used as containers for the manure. Each was filled level full. The ammonium carbonate, when used, was imbedded in the manure; 57 grams was the amount generally employed. Ammonium hydroxide was not entirely satisfactory, because the ammonia escaped rapidly, and the addition of a liquid to the manure made it too wet. The controls held acidulated manure only, and were placed two, twenty-five, thirty or fifty feet from the acidulated manure which contained ammonium compounds. In one experiment the ammonium carbonate was placed in a glass dish to which water was added, and a dish containing acidulated manure was set at a distance of one foot on each side of it.

A summary of six experiments is given below. Each dish with its contents is spoken of as a lot:

Total egg-masses in 10 lots of HCl manure evolving ammonia from ammonium carbonate	164.0
Average per lot	16.4
Total egg-masses in 4 lots of HCl manure evolving ammonia from ammonium hydroxide	14.0
Average per lot	3.5
Total egg-masses in 10 lots of HCl manure separated 1–2 feet from ammoniated lots	37.0
Average per lot	3.7
Total egg-masses in 10 lots of HCl manure separated 25, 30 and 50 feet from ammoniated lots	8.0
Average per lot	0.8

The lots which volatilized ammonia from ammonium carbonate were more than four times as attractive as the untreated acidulated lots placed near them (one to two feet), and more than twenty times as attractive as the acidulated lots placed some distance away (25 to 50 feet). In the single experiment in which an acidulated manure lot stood on each side of a dish containing ammonium carbonate and water, twelve egg-masses were deposited upon the acidulated manure, while none was found in the acidulated manure controls thirty feet distant. The oviposition response of the house fly in these experiments was roughly in an inverse ratio to the distance from the source of the ammonia.

Oviposition in Timothy Chaff and Pine Sawdust.—This series of experiments was conducted in the same manner as the acidulated manure series. The chaff and sawdust were always kept moist with water. The results are set forth in the following table:

Number	Material Used in Each Lot	Number of Lots	Distance from Ammoniated Lots	Duration of Experiments	Number of Egg-masses
1a	Timothy chaff and 241 gm. of ammonium carbonate	3		5 hours	19
b	Timothy chaff only	3	3 inches	5 hours	0
2a	Timothy chaff and 57 gm. of ammonium carbonate	1		17 hours	3
b	Timothy chaff only	1	2 feet	17 hours	0
c	Timothy chaff only	1	50 feet	17 hours	0
3a	Pine sawdust and 227 gm. of ammonium carbonate	3		99 hours	4
b	Pine sawdust only	3	12 inches	99 hours	0
4a	Pine sawdust and 106 gm. of ammonium carbonate	1		47 hours	2
b	Pine sawdust only	1	3 inches	47 hours	0

Timothy chaff which volatilized ammonia incited flies to oviposit on it within a short time. The average number of egg-masses per lot for the two experiments was 5.5, considerably lower than the average for the acidulated manure experiments. Larvæ were able to develop into normal flies in timothy chaff.

Pine sawdust was even less attractive than timothy chaff, with an average of 1.5 egg-masses per lot. Larvæ died soon after hatching in this substance.

Oviposition in Cotton and Filter Paper.—Pieces of ammonium carbonate were placed in evaporating dishes, covered with sterilized ab-

sorbent cotton, moistened with water, and exposed in a locality where flies were fairly abundant. Some of the dishes contained in addition small amounts of the following: ethyl alcoholic solution of skatol, ethyl alcoholic solution of indol, ethyl alcohol, phenol, valerianic acid, and butyric acid. In other dishes the ammonium carbonate was omitted, and the following compounds were added to the moistened cotton: ammonium sulphide solution, valerianic acid, and butyric acid. There were also controls of moistened cotton only.

For the filter paper experiments, the paper was torn into bits, moistened with water and placed over the ammonium carbonate. In one series the filter paper was stained with aqueous Bismarck brown.

Eleven experiments involving fifty-three individual lots showed positive results with only three combinations. These results are summarized below:

Material	Number of Experimental Dishes	Duration of Experiments	Number of Egg-masses Found
57 gm. ammonium carbonate + 2–5 c.c. valerianic acid + 50 c.c. water + cotton........	7	3–72 hrs.	3
57 gm. ammonium carbonate + 2–5 c.c. butyric acid + 50 c.c. water + cotton........	7	3–72 hrs.	18
57 gm. ammonium carbonate + 20–50 c.c. water + cotton........	11	3–72 hrs.	1

Butyric acid, and to some extent, valerianic acid augmented the oviposition response of the house fly when added to moist ammoniated cotton. Ammonium carbonate and moist cotton without the aid of these acids brought forth almost no response.

Discussion

The small amount of oviposition in the distantly removed controls of the acidulated manure series was probably due to the fact that the flies were coaxed into the vicinity by the odor of ammonia from the ammoniated lots and came by chance to the distantly removed lots. These experiments show that many flies went a short distance from the exact source of the ammonia in order to place their eggs in a favorable substance and it is reasonable to expect a few would stray even farther. Of course a chemical substance present in the manure, but not tried in these experiments, may have been responsible for this slight attraction, or it may be true that an attractive odor is not always necessary to induce oviposition.

Female house flies have some power which enables them to discriminate between substances with high food value for their larvæ and substances which have little or no food value. This power is not infallible. Even when volatilizing ammonia, pine sawdust, cotton, or filter paper had little attraction, while acidulated horse manure and timothy chaff showed considerable attraction. It is suggested that this food-discriminating power is either a gustatory or a "contact-odor" perception.

Butyric and valerianic acids are found in barnyard manure, and it seems probable that their addition to ammoniated cotton gives to that substance an odor which simulates to a degree the odor arising from manure. If this is true it explains why house flies are readily attracted to ammoniated cotton to which these acids have been added. It is interesting to note that butyric and valerianic acids, when added in small amounts to ethyl alcohol, increased the attraction of the alcohol to *Drosophila ampelophila*.[5]

I hope to give these questions further attention. These studies emphasize the necessity for the proper disposal of all fermenting organic substances which volatilize ammonia, and reveal possible new angles of attack in the control of the house fly.

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[5] Barrows, William Morton, "The Reactions of the Pomace Fly, *Drosophila ampelophila* Loew. to Odorous Substances," *Jour. Exper. Zool.*, Vol. 4, pp. 515–537 (5 figs.).

SOCIETIES AND ACADEMIES

THE AMERICAN SOCIETY OF ICHTHYOLOGISTS AND HERPETOLOGISTS

ON March 8, 1916, at the American Museum of Natural History, New York, occurred the inauguration and first general meeting of a new biological organization, "The American Society of Ichthyologists and Herpetologists."

Officers were elected as follows:

President, Professor Bashford Dean.

Vice-presidents, Dr. Leonhard Stejneger, Dr. Barton W. Evermann, Dr. Charles R. Eastman.

Treasurer, Mr. Raymond L. Ditmars.

Secretary, Mr. John T. Nichols, American Museum of Natural History.

Publication Committee of Copeia, Messrs. J. T. Nichols, Henry W. Fowler and Dwight Franklin.

According to the by-laws adopted, the object of the society shall be to advance the science of fishes, batrachians and reptiles. Members shall be chosen from among persons interested in the subjects, and the business of the association shall be vested in the hands of a board of governors who are not to exceed fifty in number. Membership dues are two dollars a year, a certain proportion of the receipts being assigned to the support of the publication *Copeia,* which has been issued monthly since December, 1913, to advance the science of cold-blooded vertebrates.

The president of the society, Dr. Dean, presided at the morning and afternoon sessions of the public meeting, during the presentation of the following twenty-two papers:

"The Status and Needs of Our Study of Fishes," by Professor Bashford Dean.

"Origin of the Anura" (lantern slides), by Dr. W. K. Gregory.

"The Life-history and Habits of the Star-gazer, *Astroscopus*" (lantern slides), by Professor Ulric Dahlgren.

"Some Features of Ornamentation in the Cyprinodonts," by Mr. Henry W. Fowler.

"On the Discovery of the Great Lake Trout, *Cristivomer namaycush,* in the Pleistocene of the Middle West," by Dr. L. Hussakof.

"Hibernation and Food Supply," by Dr. W. H. Ballou.

"Some Life Habits of the Hog-nosed Snake" (lantern slides), by Mr. J. Fletcher Street.

"*Anomalops,* a New Genus," by Mr. C. F. Silvester.

"The Year's Herpetological Activity at the Museum of Comparative Zoology," by Mr. G. K. Noble.

"The Dean Bibliography of Fishes about to be published by the American Museum," by Dr. Charles R. Eastman.

"Development and Habits of *Ambystoma tigrinum* on Long Island" (lantern slides), by Mr. George P. Engelhardt.

"Some Congo Amphibians and Reptiles" (lantern slides), by Mr. James P. Chapin.

"Some Reptiles of the Colorado Desert, with Remarks on Their Associational Distribution and Environmental Relationships," by Mr. Charles L. Camp.

"Native Congo Fisheries" (lantern slides), by Mr. Herbert Lang.

"Collecting Amphibia and Reptiles in Florida," by Mr. Richard F. Deckert.

"Snakes of Santo Domingo" (lantern slides), by Mr. Clarence R. Halter.

"Collecting in Borneo" (lantern slides), by Mr. D. D. Streeter.

"Notes on Long Island Sharks," by Mr. J. T. Nichols and Mr. R. C. Murphy. (By title.)

"Albinism in the Western Gopher Snake," by Mr. Tracy I. Storer. (Read by Mr. C. L. Camp.)

"The Need of a Critical Study of the Squamation of Serpents," by Captain J. C. Thompson. (By title.)

"Conservation of Reptile Life," by Mr. P. D. R. Rüthling. (By title.)

"Reptiles and Amphibia Collected in the Painted Desert" (illustrated with specimens and photographs), by Mr. Dwight Franklin.

ROBERT C. MURPHY

THE INDIANA ACADEMY OF SCIENCE

THE Indiana Academy of Science met in Indianapolis, December 3–4, and presented the following papers:

President W. A. Cogshall's address on "The Origin of the Universe."

THE SYMPOSIUM ON HEREDITY

"A Résumé of the Work on Heredity," by Dr. F. Payne.

"Fifteen Years of Mendelism; Mendelism, the Key to the Architecture of the Germplasm," by Dr. Roscoe R. Hyde.

"Heredity in Man," by Dr. Charles B. Davenport.

"A Memoir of Donaldson Bodine," by H. W. Anderson.

"Memoir of Josiah T. Scovel," by Charles R. Dryer.

"Twelve of Nature's Beauty Spots in Indiana" (lantern), by Edward Barrett.

"Concerning the Report of the Survey of Lake Maxinkuckee," by Amos W. Butler.

"A Field Trip in General Science," by B. H. Schockel.

"The Tobacco Problem," by Robert Hessler.

"Histological Changes in Testes of Vasectomized Animals," by Burton D. Myers.

"The Minimum Lethal Infecting Dose of Trypanosomes," by C. A. Behrens.

"Tolerance of Soil Bacteria to Media Variations," by H. A. Noyes.

"Some Methods for the Study of Plastids in Higher Plants," by D. M. Mottier.

"The Morphology of *Riccia fluitans*," by Fred Donaghy.

"Plants not Hitherto Reported from Indiana," by Chas. C. Deam.

"Indiana Fungii," by J. M. Van Hook.

"The Second Blooming of *Magnolia soulangiana*," by D. M. Mottier.

"Additional Notes on Rate of Tree Growth," by Stanley Coulter.

"The Effect of Centrifugal Force on Plants," by F. M. Andrews.

"Some Preliminary Notes on the Stem Analyses of White Oak," by Burr N. Prentice.

"Botanic *vs.* Biologic Gardens" (illustrated by specimens), by Robert Hessler.

"Soluble Salts of Aluminum in Water from an Indiana Coal Mine," by S. D. Conner.

"Detection of Nickel in Cobalt Salts," by A. R. Middleton and H. L. Miller.

"The Use of the Spectrophotometer in Chemical Analysis," by George Spitzer and D. C. Duncan.

"The Different Methods of Estimating Protein in Milk," by George Spitzer.

"A New Cave Near Versailles," by A. J. Bigney.

"Loess Deposits in Vigo County, Indiana," by Wm. A. McBeth.

"Volume of the Glacial Wabash River," by Wm. A. McBeth.

"A Geologic Map of the Terre Haute Region," by B. H. Schockel.

"A Bibliography of Geographical Material," by B. H. Schockel.

"Settlement and Development of the Lead and Zinc Mining Region of the Upper Mississippi," by B. H. Schockel.

"A Few Science Wonders of the Cement Age" (lantern), by F. W. Gottlieb.

"The Fauna of the Trenton and Black River Series of New York," by H. N. Coryell.

"Gamma Coefficients with Applications to the Solution of Difference Equations and Determination of Symmetric Functions of the Roots of an Equation in the Terms of the Coefficients," by Arthur S. Hathaway.

"Some Determinants Connected with the Bernoulli Numbers," by K. P. Williams.

"Some Relations of Plane to Spheric Geometry," by David A. Rothrock.

"Some Notes on the Mechanism of Light and Heat Radiations," by James E. Wyant.

"A Standard for the Measurement of High Voltages," by C. Francis Harding.

"Ionization Produced by Different Thicknesses of Uranium Oxide," by Edwin Morrison.

"Radioactivity of Richmond Water," by Edwin Morrison.

"A Student Photographic Spectrometer" (lantern), by Edwin Morrison.

"An Experimental Determination of the Velocity of Sound Waves of Different Intensities" (lantern), by Arthur L. Foley.

"A Simple Method of Harmonizing Leyden Jar Discharges" (lantern), by Arthur L. Foley.

"An Electroscope for Measuring the Radioactivity of Soils" (lantern), by R. R. Ramsey.

"Some Photographs of Explosions in Gas" (lantern), by John B. Dutcher.

"The Cause of the Variation in the Emanation Content of Spring Water" (lantern), by R. R. Ramsey.

"A Standard Condenser of Small Capacity" (lantern), by R. R. Ramsey.

"A Comparison of Calculated and Experimental Radii of the Ring System by Diffraction and an Extension of Lommel's Work in Diffraction" (lantern), by Mason E. Hufford.

"Rate of Humification of Manures," by R. H. Carr.

"An Instance of Division by Constriction in the Sea-Anemone, *Sagartia luciæ*," by Donald W. Davis.

"Data on the Food of Nestling Birds," by Will Scott and H. E. Enders.

"Two New Mutations and Their Bearing on the Question of Multiple Allelomorphs," by Roscoe R. Hyde.

"A Study of the Oxygenless Region of Center Lake," by Will Scott and H. G. Imel.

"The Lakes of the Tippecanoe Basin," by Will Scott.

A. J. Bigney,
Secretary (Retiring)